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FRUIT FALL AND ITS CONTROL BY SYNTHETIC GROWTH SUBSTANCES

by

M. C. VYVYAN, M.A., D.Sc.

East Malling Research Station

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FRUIT DROP AND ITS CONTROL BY SYNTHETIC GROWTH SUBSTANCES

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FOREWORD

The practical horticulturist has good grounds for his increased interest in the use of synthetic growth substances.

They have already been found to facilitate the rooting of cuttings of many plants. There are indications that, properly understood, they may be useful in grafting. Moreover, under certain conditions, they can profitably be used to induce parthenocarpy. And now a further use has been found which brings the millennium a stage nearer. The inspired work of a small band of scientists has led to results of immediate practical importance, in that they have shown how, under certain circumstances, spraying with growth substances retards fruit fall. If the process can be regulated to suit different varieties and different seasons, so that fruit can be held on the trees until the desired stage of ripeness is reached or until another urgent operation elsewhere on the farm has been completed, the fruit grower stands to gain considerably.

No wonder then that workers in different parts of the world are busy investigating the possibilities. As a result, the practical value of treatment with growth substances in controlling the drop of nearly ripe fruit has been clearly proved for some varieties, but is still in doubt for others. The chief immediate need is for substances which (a) will work with varieties which do not respond to substances now used, (b) will be effective for a longer period, and (c) will control other forms of drop, e.g., spray-induced drop. Widely scattered workers have, inevitably, been concerned mainly with their own local problems and varieties, and as a result investigations of some problems have been replicated many times, while work on others has been somewhat scrappy.

And precisely because of the rather conflicting evidence and of the multitude of different methods, materials and results, the Bureau is particularly grateful to Dr. Vyvyan for gathering these scattered observations into a single review which may well form the basis of a more co-ordinated attack.

Dr. Vyvyan's willingness to sift the evidence, his skill in tabulating data which would appear to the ordinary mortal almost incapable of tabulation and his suggestions with regard to experimental work should prove invaluable.

D. AKENHEAD.

INTRODUCTION

Some varieties of fruit trees, including several of great economic importance, tend to shed much of their crop shortly before it is ready to be picked. This tendency is more marked in some seasons, and certain localities, than in others. Fruits that fall in this " Pre-harvest Drop " may be marketable, especially if straw has been placed under the trees to minimize bruising, but they are often undersized, poorly-coloured, and unsuitable for storage ; some are inevitably damaged by striking branches in their fall. Under normal conditions, they usually fetch a lower price. Fruit picked early to avoid the drop, often suffers from some of the same faults.

Much interest has therefore been aroused by the recent discovery (Gardner, Marth and Batjer, 1939) that dilute sprays of certain " Growth Substances " provide considerable control of this drop. Since the first announcement, in 1939, the results of many further experiments on the same lines have been published by various authors ; most of these have been done in the U.S.A., where these sprays are now used on a large commercial scale,* but some have been reported from Canada, Australia, England and the Netherlands.

A clear and concise summary of the main results of the work done under United States conditions has been published (Batjer, 1943), but there seems a need for a fuller review to cover that carried out in other countries and at a more recent date. This paper is an attempt to meet this need.

The " Pre-harvest Drop " is only the last of a series of losses of potential crop and most of these losses seem to be due to abscission processes. Brief outlines of our knowledge of these earlier losses and of the abscission processes concerned are therefore included.

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* Batjer (1943) estimates that 30,000 to 35,000 acres were sprayed in 1940, from 50,000 to 55,000 in 1941 and from 75,000 to 80,000 in 1942.

Part 1 LOSS OF POTENTIAL FRUIT

A DEVELOPMENT FROM BLOSSOM-BUD INITIAL TO RIPE FRUIT

The maximum number of fruits on a tree depends on the number of blossom-buds initiated, but the number that reach maturity is much less owing to heavy losses at various stages in development.

The course of development from initial to ripe fruit, in so far as it is known, is fully described in most text-books and need only be outlined here.

The initiation of blossom-buds in the pome and stone fruits occurs mainly in the season before the blossoms open. The late blossoms that occasionally open, especially after frosts, may be initiated in the current season, but they rarely produce an appreciable proportion of the crop (Painter, 1939). The true initiation, or irreversible change from vegetative to reproductive activity, seems to occur some weeks before the blossom primordia can be identified microscopically (Struckmeyer and Roberts, 1942).

Differentiation of floral parts proceeds during the growing season, but the stage reached by the time of leaf-fall seems to vary ; the final stages, including the formation of the pollen and embryo-sacs seem to be postponed till the spring. Development is slower during the dormant period and little or no morphological change occurs during the period of rest. At the onset of spring, rapid differentiation and development are renewed, the buds swell and burst, the blossoms emerge, enlarge, and open and are ready for pollination and fertilization. Success here means that pollen has reached and germinated on the stigmatic surface, pollen-tubes have grown down the style and reached the ovarian cavity, and the two sperm nuclei have entered the embryo-sac and fused respectively with the egg nucleus and fusion nucleus (or anti-polar nuclei) to form the embryo and endosperm. The blossom has become a fruit. Further progress varies in detail with the kind of fruit ; the apple is taken here as an example.

After-petal-fall the young fruit grows rapidly for two or three weeks, according to variety, at a more or less exponential rate (Archbold, 1932). During this period the rate of respiration starts high but falls progressively to about one-fifth its early value (Kidd and West, 1937). Growth is mainly by vigorous cell-division and the seeds rapidly develop. Most of the nitrogen found in the mature fruit is absorbed during this phase (Archbold, 1932). Growth now becomes more uniform, or linear, and is due mainly, or entirely, to enlargement of cells and intercellular spaces. Starch appears in the cells for the first time three or four weeks after petal fall, according to the variety. Growth may continue at a uniform rate until the fruit is ripe, but it slackens off in some late-maturing varieties (Tukey and Young, 1942) or ceases altogether at leaf-fall (Archbold, 1932). Starch increases to a maximum, then decreases ; sugars increase, at first by absorption, then by hydrolysis of the starch. The rate of respiration steadily falls until maturity is approached, then rises rapidly to a peak known as the " climacteric " (Kidd, 1934 and 1935) ; this may be reached on different dates by different fruits on the same tree (Kidd and West, 1938). Broadly speaking, the fruit may now be considered ripe. Respiration now falls as over-maturity sets in. Fruit for storage must be picked before the climacteric, especially in the case of pears. If not picked, the fruit ultimately becomes " loose " through the formation of an abscission layer at the base of its stem and is shed by the force of its own weight, or is shaken off by the wind.

Pre-harvest drop is due to the premature development of this abscission layer.

B. PRE-BLOSSOMING LOSSES

Little seems to be known about the losses, if any, that occur during early stages of differentiation, but conditions during this period may cause defects in floral parts and may influence the size of the blossoms and spurs, and determine the degree of differentiation achieved before the onset of winter, and thus affect ultimate survival value.

Blossom-buds may be killed or damaged by frost or low temperatures in the autumn, especially if in an advanced stage of differentiation (Roberts, 1937) or if they have developed in the shade. They seem relatively resistant during the rest period. Destruction or damage is more common in the spring, either from frost, or from low or fluctuating temperatures, and especially in the " green-bud " stage and under conditions of low nitrogen. At all stages, there are marked varietal differences in susceptibility to damage.

Certain insect pests and fungi may destroy the buds during this period, and tar oil or petroleum oil sprays applied at, or just before, bud break, may cause the buds to die and fall out. The density of the oil deposit seems more important than the time of application, especially in the Victoria plum (Steer and Moore, 1941).

C. SHEDDING OF BLOSSOM AND YOUNG FRUIT

Losses may occur at any of the important stages in development that are crowded into the critical period of four or five weeks following the opening of the blossoms.

1. PRINCIPAL CAUSES

The chief causes of shedding of blossom and young fruit seem to be :—

(*a*) Structural Defects

Defects in flower parts may arise at an early stage from varietal tendencies, winter injury, spray damage or insect attack. Defective pistils seem to be very common and may be responsible for early shedding of blossoms in the apple (Murneek, 1933) and the plum (Dorsey, 1919). Defective ovules have also been reported. Defective anthers seem more rare and less important, since pollen from other blossom may be available.

(*b*) Non-pollination

Self-pollination may fail even in perfect, self-compatible, hermaphrodite blossoms, if the stigmatic surface is unfavourably placed with respect to the anthers (Srivastava, 1938c). Cross-pollination may be prevented by lack of suitable pollen, or by the absence of insect carriers, or their inactivity owing to unfavourable weather conditions. Even if pollen reaches the stigmas, it may be washed off by rain before it can exert even a stimulus. In certain varieties, some fruit may develop parthenocarpically without the stimulus of pollination (Gustafson, 1942). This is sometimes called *autonomic parthenocarpy*.

(*c*) Non-fertilization

If pollination has been achieved, fertilization may fail from various causes, the chief of these seem to be :—

(i) Gametic sterility. Some or all of the pollen grains, or embryo-sacs, may be non-viable owing to meiotic irregularities resulting in unbalanced gametes. This condition seems to be common in polyploids containing an uneven multiple of the basic number of chromosomes, especially in triploid varieties of apple, where it is " more pronounced on the male than on the female side " (Modlibowska, 1945). Such pollen grains either fail to germinate or, if pollen tubes are formed, these usually burst early, or, if they reach the ovaries, give rise to unbalanced embryos (Modlibowska, 1945).

(ii) Incompatibility. The pollen-grains and embryo-sacs may both be viable and each capable of taking part in fertilization if appropriately paired, but may be mutually incompatible. As both may vary in genetic composition in the same flower, there are degrees of incompatibility. According to Modlibowska (1945) " Incompatibility in apples and pears is due to physiological reactions occurring between the pollen tube and the stylar and ovarian tissue . . . These reactions are genetically controlled . . . pollen cannot function in a style or ovary which carries the same incompatibility genes . . . as the pollen."

(iii) Adverse weather conditions. Cold spells may slow down the growth of the pollen-tubes so that these are cast off with the styles before they can reach the ovules. Premature shrivelling of the styles, owing to hot spells or dry winds, may have the same effect.

(iv) Failure of double fertilization. Apparently the fusion of the second sperm nucleus with the anti-polar nuclei, or fusion nucleus, sometimes fails to occur. This may prevent the formation of the endosperm, and thus that of the embryo.

Pollinated blossoms sometimes produce fruit, even in the absence of fertilization, especially in pears (Gustafson, 1942). Such fruits are usually seedless, but sometimes seeds too are formed parthenogenetically. Certain treatments, especially with growth substances, sometimes induce parthenocarpy. Lewis (1942) produced parthenocarpic fruits in the pears Conference and Fertility by exposing the blossoms for 18 hours to a temperature of —5° F.

(*d*) **Abortion of Embryos**

Abortion may arise from genetical causes or from unfavourable nutritional conditions and usually results in the shedding of the fruit. Some fruit may set in spite of abortion, but are without seeds. Pome fruits, which have many ovules, may have varying numbers of seeds. Those with few seeds are usually smaller, and more liable to drop, than those with many (e.g., Southwick, 1940, Heinicke, 1917, Tydeman, 1944).

2. CONTRIBUTORY FACTORS

Within a variety, small blossoms seem to shed more readily than large (Srivastava, 1938c, Gayner, 1941). The larger the spur, and the more blossom it carries, the higher the percentage of set (e.g., Heinicke, 1917, Blasberg, 1943). Spur position may also be important.

Drop is usually most severe in young and in vigorously growing trees ; probably owing to severe competition from the numerous shoots that are in active growth while the fruits are young.

Nutritional conditions seem very important ; for example, nitrogen seems to favour the early stages in setting, but at later stages tends to favour shedding. Shade seems to promote dropping, which is usually severe in crowded trees and lower limbs. Set is usually better on the sunny than on the shaded side of the tree (Srivastava, 1938b).

Varietal factors, in addition to those involved in non-viability and incompatibility, apparently play an important part, for the percentage of blossoms set varies widely with the variety (Wallace and Spinks, 1940).

Frosts can be devastating and completely destroy a whole crop. Young fruits often seem more susceptible than open blossoms. Marked varietal differences in resistance to frost seem to exist and are imperfectly understood ; they are not necessarily related to time of blossoming.

3. WAVES OF DROPPING

Microscopical examinations to determine the cause of loss can only be carried out on a limited scale ; some observers have sought to find the cause by determining the time of shedding. Dropping tends to occur in waves, separated by intervals of little or no loss, but the number of waves and their relative magnitude seem to vary. In the apple, Murneek (1933) reported four waves, occurring at intervals of 12 to 14 days, but most authorities recognize only two—a " First Drop " and a " June Drop,"--though many agree that these may be compound in nature and show secondary peaks. Srivastava (1938a) found two waves in the pear varieties he examined, but some authorities consider there are three. Three waves seem rather characteristic of the stone fruits ; they have been reported for the plum (Dorsey, 1919), the sugar prune (Bowman, 1941b) and the sour cherry (Bradbury, 1929). But it has been found that shedding due to various causes, such as non-fertilization and embryo abortion, may occur in the same wave, and shedding due to a single cause may occur in different waves ; time of drop is therefore no infallible guide as to cause. Time of initiation of drop, when it can be determined, would seem a better guide. Several workers (e.g., Srivastava, 1938, Tydeman, 1938 and 1944), have shown that dropped fruits are usually smaller than those retained on the tree and Bowman (1941b) determined the dry weight of samples of dropped fruit and fruit retained by the tree on a series of dates, and estimated the time of initiation of the dropping " by tracing back the dry weight of the dropped fruit to the growth curve of the setting fruit " and found the time from initiation to dropping considerable and varied with the different waves.

The immediate cause of shedding is the formation of an abscission layer, and the time when this layer is initiated may possibly be more important than the time of actual shedding. MacDaniels (1937) and McCown (1939) have shown, for certain varieties of apples, that the abscission layer responsible for "June Drop" involves several successive cell-divisions. As McCown (1943) found no trace of such a layer in the stems of fruits that survived the "June Drop," it can be inferred that, once the layer is initiated, the fall of the fruit is inevitable. The complexity of the process, in the case of this drop, suggests that the period between initiation and shedding must be several days, if not weeks.

4. PROPORTION OF BLOSSOM TO BECOME MATURE FRUIT

The earlier and later waves of shedding tend to be inversely proportional to one another; this has been shown for the apple by Heinicke (1917), and for the sour cherry by Bradbury (1929). There is thus a natural tendency for the crop to be adjusted to the bearing capacity of the tree. Crane (1923) states that "taking two trees of equal size and age, one may flower twice as freely as the other, but owing to the limited number of fruits that trees are able to carry, approximately the same number . . . may reach maturity." Presumably, too heavy a crop leads to severe competition and results in embryo abortion. Howlett (1943), when using sprays to reduce set, found that a reduction in set after the first drop was more or less obliterated by a reduction in shedding at the second drop. According to Heinicke (1917) only one-third to one-sixth of the flowering spurs retain a fruit till maturity. There seem to be marked varietal differences; thus Wallace and Spinks (1940) found that the harvested fruit represented from 5·3% to 8·6% of the blossom trusses in the case of Edward VII apples and from 22% to 27·5% in the case of Allingtons. According to Bowman (1940), "For a normal crop only one fruit set to about four or five spurs"; this is in accord with results obtained by other workers, e.g., Hoffman (1942), Howlett (1943), Van Doren and Hoffman (1943). As each spur normally carries several blossoms, the set expressed as percentage of blossoms is still lower. Crane (1923) found that a 4% set frequently gave a full crop, and Hatton (1927), working with young trees, found that the set varied from about 3% to about 11% according to the variety of rootstock used.

The percentage set in the stone fruits seems to be sometimes rather higher. Bowman (1941b) got a 21% set in the sugar prune but described the crop as heavy. Crane and Brown (1937) obtained a good yield in the sweet cherry from a 22% set of pollinated blossom, and Bradbury (1929) reported a set of from 25% to 50%, according to season, in the sour cherry. Detjen (1926) found a set of 16·4% and 25·9% in two peach trees and reported that the trees were so heavily laden at harvest time that they had to be propped, but a set of ·73% and 1·75% in two trees of the plum variety Terrell yielded only a fair crop. A higher percentage set than that required for a full crop results in under-sized, poor quality, fruit. Bowman (1940), speaking of pome fruit, points out that "A plentiful set . . . is detrimental to leaf area and blossom bud differentiation. It reduces the leaf area of the secondary spurs which arise below the cluster of blossoms by half." In such cases, thinning is required if good quality fruit is to be obtained; many workers have been experimenting with sprays to reduce set. Moreover, there are often local concentrations of blossom; for example Painter and Wates (1939) found that thinning Common Plum to 1 in. intervals removed 61% of the fruit while thinning to 2 in. removed only a further 7%. In an "off" year the blossoms may be far too few for a full crop, but even here there may be local concentrations, such as the six or seven blossoms on an apple spur. So long as a fruit is on the tree it tends to use up material, hence, if a fruit is going to drop, the sooner it does so the better. If it could be ensured that little or no drop would occur after thinning, reduction of the number of blossoms to that required for a full crop would seem the ideal policy; but the danger of heavy "June" and pre-harvest drops makes this practice unsafe. Any method for the control of these drops is therefore of great value.

D. THE PRE-HARVEST DROP

This drop differs considerably in certain respects from the earlier drops, though some of the conditioning factors may be the same. It does not seem to be due to failure at some essential stage in development, but rather to the premature formation of the abscission layer responsible

for the normal shedding of ripe fruit. In certain apple varieties, at any rate, this layer is simpler than that concerned in the " June Drop " and involves no cell-divisions (MacDaniels, 1937 and McCown, 1939). It is probable that the period from its initiation to the shedding of the fruit is shorter and, possibly for this reason, the dropped fruits are not necessarily smaller than those retained on the tree (Archbold, 1937 and van Stuivenberg, 1941). Fruit dropped after the commercial picking date may even be larger and in the same stage of physiological activity (Archbold, 1932). Indeed, in some varieties it seems to be the larger fruits that are lost in the pre-harvest drop (van Stuivenberg, 1941). Indirect evidence suggests that the formation of the abscission layer is normally held in check by the presence of natural growth substances and its development is due to the local exhaustion of these substances or the cessation of their flow from other parts of the plant. Leaf-fall is said to be due to the same cause. The intensity, time and duration of the pre-harvest drop are influenced by a number of factors, including seasonal and climatic conditions, cultural treatments and varietal and morphological characteristics.

1. EFFECT OF WEATHER CONDITIONS

Many authors have found that high temperatures tend to increase the drop. Cole and McAlpin (1941), working in Australia, noted that heat waves " Especially when followed by cold nights, frequently cause excessive drop." Cool weather, on the other hand, tends to reduce the intensity, though it may prolong the duration, of the drop, or it may postpone it till after maturity. Winds, by shaking down loosening fruit, may cause waves of heavy shedding (Gardner, Marth and Batjer, 1940). Sometimes these are followed by periods of subnormal drop. Severe gales may tear fruit, that is not loose, from the tree (Cole and McAlpin, 1941, Hilton, 1944) ; this is hardly true pre-harvest drop. Seasonal differences may be considerable. For example Hoffman (1942) found identical trees of McIntosh dropped only 1·5% in 1940, which was a cool season, and 25% in 1941.

2. EFFECT OF CLIMATE

Intensity and duration of Pre-harvest Drop varies greatly with the climate. For example, McIntosh, according to Southwick (1940), tends to drop 50% of its fruit in Massachusetts, up to 35% in New Hampshire, from 1% to 15% in Maine, and from 10% to 15% in Connecticut and Rhode Island. Possibly other factors besides climate are concerned. Gardner (1940), referring to New York conditions, points out that the drop is spread over a longer period in southern districts than further north. Enzie and Schneider (1941) report that all apple varieties grown in New Mexico tend to drop continuously from the June drop until harvest. Soil conditions and altitude may have been involved here. On the other hand, Hoffman *et al* (1942) report that " When such late varieties as Baldwin and Spy are grown in northern altitudes, cool weather will in many seasons prevent an excessive drop until the fruit has reached or passed prime picking condition." Gardner, Marth and Batjer (1939) pointed out that " Climate and weather influence fruit dropping and are therefore important factors determining the feasibility of growing certain varieties in a given region," and they suggest that " It is conceivable that elimination of the danger of dropping, in addition to safeguarding those varieties which consistently show this characteristic, may also widen the growing range of certain others, which drop badly only in the more southern regions."

3. EFFECT OF CULTURAL TREATMENT

Several writers (e.g., Southwick, 1940) have found that the increase in crop from the use of nitrogenous fertilizers, or their equivalent, may be offset to a considerable extent by an increase in the pre-harvest drop. Shade and overcrowding also tend to promote drop (Hoffman, 1941b), but well-pruned trees, well-sprayed with mild fungicides and having a large efficient foliage, are likely to show comparatively little drop.

4. LOCAL VARIABILITY

Even small differences in locality may be important ; for example Southwick and Shaw (1941b) found that "no two McIntosh orchards are alike. Even similar appearing orchards in

close proximity often behave differently in regard to pre-harvest dropping of fruits." The same author reported variability between neighbouring trees in the same block, and this has been found by other workers, e.g., Gardner *et al* (1940), Burkholder and McCown (1941) and Swarbrick (1943). This variability may sometimes be the result of differences in soil conditions but it seems to be due sometimes to differences in the relative weight of the crop borne by the trees (Greve *et al*, 1941).

5. VARIETAL DIFFERENCES

Fraser (1924) states that certain varieties of apple " drop heavily before reaching maturity, especially in dry seasons . . . Winds will cause others to drop readily when they have reached maturity . . . Other varieties hang well after reaching maturity." He gives examples of each. Similar differences have been remarked on by many authorities (e.g., Southwick, 1940, Hoffman, 1941b and MacDaniels, 1937). The evidence, however, is rather conflicting ; certain varieties, such as Jonathan and Grimes, are described sometimes as heavy droppers and sometimes as little prone to the trouble. These apparent discrepancies are probably due to differences in the local or climatic conditions under which the various investigators worked.

Duration of dropping, as well as its intensity, seems to be a varietal factor. For example, Gardner *et al* (1940) state that some varieties, such as Stayman Winesap, may show a disastrous drop almost " overnight," while others, such as McIntosh, " may fall steadily for several weeks." Other authors, e.g., van Middlesworth (1942) have found the same. Bramley's Seedling, at East Malling, seemed to have a long period of drop in 1942 and 1943.

Certain morphological characters seem to be associated with differences in susceptibility to pre-harvest drop. For example, according to MacDaniels (1937), " a long flexible pedicel permits the apple to swing back and forth without strain at the point of attachment . . . Long pendulous spurs . . . have the same effect." Golden Delicious is named as a variety with the first character, Twenty Ounce as one with the second, Rome Beauty as having both. Varieties, such as McIntosh, with short stiff pedicels attached to short stiff spurs, are very liable to have their fruit jerked off by gusts of wind. Williams Early Red seem to be an exception, it has a long pedicel but is very prone to drop. The tendency to bear on long twigs, as in Northern Spy, seems a disadvantage, because, according to van Meter *et al* (1940) these " allow the fruit to whip and be bruised."

According to several authorities (e.g., Gardner *et al*, 1939, Southwick, 1940, Hoffman, 1941b and Batjer, 1942a), varieties that ripen early tend to drop more heavily than those that ripen late ; but there are many exceptions. The differences may be related to the prevailing temperatures at the time when maturity is being approached. Perhaps the more rapid growth rate and more active physiological condition often found in early varieties play a part.

Drops before maturity sometimes seem to occur from a rather different cause and probably without the formation of an abscission layer. For example, according to Whittaker and Mackenzie (1944), " Jonathan is an apple prone to carry a large proportion of its fruit in clusters, and as these . . . size up . . . considerable numbers are pushed off." This probably occurs in some other varieties of similar habit, e.g., Bramley and Cox. As an abscission layer is probably not involved, control by inhibiting its formation is not likely to be successful here. Early thinning to a single fruit per truss would seem a more appropriate measure. These authors point out, however, that this drop is not altogether a disadvantage as it provides a natural thinning process. On the other hand, if two apples on the same spur have grown to a considerable size before one pushes the other off, both are liable to fall.

Part 2 THE ABSCISSION PROCESSES RESPONSIBLE FOR SHEDDING

In some plants, such as the strawberry, loss of fruit is by decay *in situ* without detachment from the plant. In deciduous fruit trees occasional fruits may be lost in the same way, or may become mummified in position, but most losses of blossoms and fruits are due to abscission processes—they are shed, somewhat like leaves at leaf-fall. Similar processes are responsible in some plants, such as the poplar, for the casting off of small branches.

The abscission process is a separation between, apparently healthy, living cells and is achieved, according to Pfeffer (1903), by the " partial or complete conversion of the middle lamella of the common partition-wall into substances which imbibe water and swell or dissolve, so that a slight strain suffices to cause separation . . . Frequently the weight of the organ or the tendency of the cells to become rounded is sufficient for this purpose." The common walls between non-living cells, such as the xylem, do not seem to become separated in this way, and these elements are broken across either before, or at the time of, shedding.

Often there is a specialized region, or abscission zone, approximately where the abscission will ultimately take place. This layer is usually composed of rather small cells and, where it occurs at the base of a leaf petiole or fruit pedicel, it is sometimes marked by an external constriction and is known as the constriction zone. The actual layer, formed by the abscission process, is not always within this zone, though it is usually near it (McCown, 1943). Moreover, abscission layers can be formed in regions where no such zone has previously been differentiated.

A. ABSCISSION WITH, AND WITHOUT, CELL-DIVISION

It is generally recognized that there are two main types of abscission process ; Lloyd (1927) describes these as : " (*a*) Separation of cells *in situ* by chemical alteration of the middle lamella and adjacent secondary walls, and (*b*) Separation of cells produced by renewed meristematic activity followed by chemical changes in the walls of the same kind." These two types seem to be alternatives, and either may occur in a single fruit pedicel. Clearly there must be some difference, or differences, in the conditioning factors in the two cases, and the control measures required to prevent the process may be different also. MacDaniels (1937) and McCown (1939 and 1943) have shown that the abscission process responsible for the shedding of young apples in the " June Drop " is of the type with cell-division, but the process involved in the pre-harvest drop of nearly ripe, and the drop of ripe fruit does not involve cell-division. This difference in the character of the abscission process in the two cases may possibly account for the successful control by sprays in the one case and their apparent failure in the other.

In the earlier drop, whether of blossom or young fruit, the tissues are in a less differentiated state, and active cell-division may possibly still be occurring. In the apple, according to McCown (1943), the differentiation of the abscission layer in blossom and young fruit occurs in the " basal portion of the pedicel." He found that " cells in all tissues underwent division in the formation of the . . . layer." It was usually formed " within the limits of the constriction zone " but occasionally " distal " to it. " The resulting layer was six to eight cells in width." He found that these layers were not formed in the pedicels of fruit that survived the " June Drop." It appears, therefore, that once progress towards the formation of such a layer has reached a recognizable stage, drop has become inevitable. This seems in accord with the view of Bowman (1941a) that the June and earlier waves of shedding are initiated some considerable time before they actually take place.

McCown (1939) considered that the tissues of the pedicels of the maturing fruit could be considered mature by the time the June drop ended ; this was shown by various anatomical features which he describes in full. Chief amongst these were the presence of numerous stone

cells in pith and pericycle and fibres in the pericycle, " very definite bands of secondary phloem and xylem, and the rather extreme thickening . . . of the cells of the cortex and of specialized cells in the abscission zone." This zone persisted, but did not pre-determine the path of abscission layers formed after the June drop. The pre-harvest drop of apples was found to be brought about by abscission layers whose formation was not preceded by secondary cell division. This " abscission of mature pedicels . . . was initiated independently in pith and cortex. In the pith, cell separation was preceded by swelling of the middle lamella and of the secondary wall and elongation of the cells . . . In tissues other than the pith, there seemed to be less breakdown of the secondary wall accompanying the dissolution of the pectic compounds of the middle lamella. Vessels and fibres in the path of separation were ruptured." MacDaniels (1937) had already shown that " in the abscission process at harvest time there is apparently no proliferation of cells in the abscission layer."

B. SUCCESSIVE ABSCISSION LAYERS

Several cases are on record where the formation of one abscission layer has been followed by that of another. Sometimes both are of the same type, sometimes they are of different types. Lloyd (1913-14) observed an instance of this in *Impatiens*. Here two abscission layers were formed—apparently both without cell-division—the upper first and the lower some 2 to 3 mm. below it. Sometimes in nature the distance between the layers is greater. This seems to be the case in the abscission of young fruits of the mango and avocado. Here the fruit in each case is borne on a short stalk and is cut off at the point of its junction with the stalk. Barnell (1939) has described the process in the mango as a cleavage " along the middle lamellæ . . . the cells and contents remaining undamaged. There was no evidence of suberization nor of the formation of an abscission cambium. After the fruit has fallen, the stalk left on the plant begins to wither and dry out and when this is well advanced, a cambium cuts it off." He found the process in the avocado very similar ; at the time of the abscission of the fruit by cleavage along the middle lamellæ, there was no trace of an abscission cambium at the base of the stalk. But after the fruit had fallen, an abscission cambium developed at its base as in the mango, but more rapidly, and cut it off from the tree. In both these instances, an abscission process with cell division followed one without.

A somewhat similar succession of abscission layers seems to occur in the apple when blossoms, or young fruits, are shed. Here the pedicels, or stems, of the blossoms or fruits are borne at the tip of a short stem commonly called the " bourse " or the " clusterbase." McCown (1943) calls this tip the " peduncle " and has described the succession of changes as follows : " Following the fall of the terminal flower or immature fruit, the stump of the peduncle abscissed immediately above the most distal flower remaining in the cluster. When all flowers or immature fruits . . . dropped, successive portions of the peduncle abscissed following the differentiation of a series of two or more absciss layers, the entire peduncle being shed. These layers also were formed by cell division, and in origin and appearance they resembled the absciss layers involved in the shedding of the pedicels." Here the succession of abscission layers was all of the same kind—with cell division.

Large scars, resulting from the abscission of the apex of the peduncle, may often be seen on the bourses of apple trees and, if examined late in the season, may easily be mistaken for the scars of stems of mature fruit.

C. VARIETAL DIFFERENCES IN DEVELOPMENT

Certain varietal differences in the course of development of the abscission layer in mature pedicels of the apple have been reported, and are of interest, as they may be, in part, responsible for differences in susceptibility to pre-harvest drop and response to control measures. In the first place, according to MacDaniels (1937), " The chemical changes which cause the collenchyma to split easily apparently take place very rapidly in some varieties and more slowly in others accounting in part for varietal differences in abscission." And in this connection, it may be pointed out, that the minimum period between the initiation of an abscission layer and the resulting shedding of a fruit, is likely to be far less in the case of mature fruit where no secondary

cell-division is involved, than in the case of immature fruit or blossoms, where a layer, some six to eight cells thick, must first be formed by cell-division.

In the second place, MacDaniels (1937) has reported certain anatomical differences in the abscission layer. In McIntosh—a heavy dropper—the layer was relatively free from sclerenchyma, had usually no fibres and few stone cells, and had a smaller cross-section owing to the constriction being deeper.

Lastly, McCown (1939 and 1943) found differences in the position of the layer and in the part initiated first. In McIntosh (1943), " pith initiation usually preceded initiation . . . in the cortex. Separation usually occurred within the limits of the constriction zone." While in Golden Delicious " cortical abscission preceded initiation of pith abscission as a rule," and was usually " distal to the constriction zone." There were indications that Grimes Golden behaved like McIntosh, and Rome Beauty, Fameuse and Delicious like Golden Delicious.

D. FACTORS CONDITIONING ABSCISSION

The factors responsible for the initiation and completion of an abscission layer have been sought by many workers but are still somewhat obscure. Water relations seem important ; organs drying out are liable to be shed. But abundant water, on the other hand, seems to be required in the region where the layer is to be formed. Too rapid drying out may prevent abscission ; for example, in severed shoots, leaves and fruit often wither *in situ* without falling, thus showing that no abscission layer is functioning. Very wet weather, moreover, sometimes results in shedding. Light intensity and temperature are apparently sometimes important factors.

Some light on the problem seems to be thrown by manipulative experiments. Removal of the leaf blade is usually followed by the fall of the leaf stalk, removal of a fruit by the shedding of the fruit stem (Heinicke, 1917) and in certain plants, such as *Impatiens*, removal of the apical portion of a shoot by the abscission of the portion of internode above the uppermost surviving leaf or lateral shoot. The abscission processes involved do not seem to be the result of wound stimulus arising from the injury, for Lloyd (1913-14) has shown that varied and extensive injuries do not result in abscission, provided they do not completely cut off the organ above. These facts are consistent with the view that the initiation of an abscission layer is due to the interruption of the flow of some stimulus, or of some substance, from above, or alternatively, of a similar flow away from the abscission zone. Recent work, described in the next paragraph, has given some indication of the existence, and possible nature of such a substance.

E. GROWTH SUBSTANCES AND ABSCISSION

Several workers have found that treatment with certain growth substances will prevent the fall of petioles from which the laminæ have been removed, or peduncles from which the young fruits have been removed. Portheim (1941), who has reviewed the earlier work, used the dwarf bean Canadian Wonder and found that " after removal of lamina, abscission of the distal joints normally takes place. This process can be inhibited by the action of heteroauxin applied in agar discs, the maximum inhibition being obtained when the discs are attached on or near the distal joint. The inhibition is progressively less pronounced, the greater the distance between the joint and the disc ; in effect the heteroauxin prolongs the life of these structures." He expresses the view that " this is achieved by the power of the heteroauxin to increase the supply of water to the joints, which are thereby enabled to remain fresh for a longer period." But he cites other experiments in which " the joints remained attached in spite of the fact that they became desiccated " and others in which joints fell off in saturated air unless supplied with heteroauxin, and concludes that " This indicates that the ability of the heteroauxin to prolong the life of the joints must be partly dependent on some other factor than that of ' drawing ' water to the joint."

It was observations of the persistence of the stubs of petioles on cuttings treated with growth substances that led Gardner, Batjer and Marth (1939 and 1940) to try the effect of these substances on abscission of fruit. They found that certain naphthalene derivatives had a marked effect on the pre-harvest drop of many apple varieties, but little if any on the " June "

drop. The difference in response may be related to that in the abscission layers concerned. It is curious that indole derivatives, so effective with leaf petioles, proved of little value in preventing pre-harvest drop. Their effect on " June " drop does not seem to have been examined and would seem worth investigating. Another anomaly seems to be provided by the Elberta peach and Stewart apricot ; here sprays of naphthalene derivatives (Hesse and Davey, 1943) had little effect with the peach where the drop seemed to be comparable with the pre-harvest drop in apples, but had considerable effect with the apricot where the drop seemed of a different character, consisting largely of immature fruits suffering from embryo abortion. The nature of the abscission layers concerned are not known.

Although growth substances may inhibit the abscission of leaf stalks, whose blades have been removed, or fruit stems, whose fruits, are approaching maturity, this does not necessarily prove that the natural inhibition of abscission, where the leaf is intact or the fruit unripe, is due to the flow of an actual growth substance from the leaf blade or the fruit. It is possible that these organs merely transmit something, either a stimulus or a material, which is necessary for the formation or activation of the growth substance in the abscission region. Examination of the transport of natural hormones from leaves and from young and old fruits might provide interesting information.

Part 3 EXPERIMENTAL METHODS

Before reviewing the results obtained and the conclusions reached by the various investigators, it seems desirable to examine the methods adopted in planning the experiments, recording the results and interpreting the data.

A. LAY-OUT OF EXPERIMENTS

1. WHOLE-TREE METHOD

Most investigators have used the whole tree as their experimental unit, spraying some and leaving others unsprayed as controls or " check." This method has the advantage that drops from different units do not tend to get mixed up, unless the trees are very crowded and overlap, in which case it is better to use units made up of several trees (Vyvyan, 1946). Trees, however, often vary greatly in crop and dropping tendency, and this may lead to distorted results if those with a tendency towards a heavy drop chance to be allocated to some particular treatment. To meet this difficulty many workers have used the normal method of randomized blocks (e.g., Davey and Hesse, 1943, Hesse and Davey, 1943, Enzie and Schneider, 1941, Berry and Swarbrick, 1942, Vyvyan, 1941, 1942, 1943 and 1946) or the latin square (Hesse and Davey, 1943). Tendency to drop, however, is not necessarily closely related to the position of the tree on the ground, but seems to be connected rather with the size of the crop relative to that of the tree; many workers, therefore, have adopted a different method of grouping. Gardner, Marth and Batjer (1940), for example, chose trees as far as possible of equal size and crop, but found it a greater help to delay spray application until drop was " well underway in order to group trees of similar dropping characteristics for treatments." Enzie and Schneider (1941) seem to have used the same method. Muneek (1940a), to ensure that any bias due to variability in drop reduced rather than exaggerated the apparent effect of the treatment, wherever possible selected for spraying the trees that carried the larger load of fruit, as these might possibly be " subject to greater fruit abscission."

2. HALF-TREE METHOD

Some investigators, for example, McCown and Burkholder (1940), Overholser, Overley and Allmendinger (1943), Hilton and Spurr (1943) and van Stuivenberg (1941), have sought to reduce variability by spraying half each tree and leaving the other half as the check or control.

This method has two advantages: it provides twice as many units for the same number of trees and it takes advantage of the fact that the two halves of the same tree often behave more alike than two separate trees. McCown and Burkholder, however, found that the dropping tendency was very different in western and eastern halves of trees and those of each aspect had to be allocated in equal proportions to each treatment. There is the further difficulty that the drops from the two halves tend to get mixed up on the ground; Hilton and Spurr (1943) got round this by picking a lane 2 ft. wide through each tree before applying their treatments. van Stuivenberg (1941) took a similar precaution.

3. LIMB METHOD

Several workers have cut down unit size still further by using tree limbs (Gardner, Marth and Batjer, 1940, Ellenwood and Howlett; 1943, Hitchcock and Zimmerman, 1941 and van Stuivenberg, 1941). This method involves some practical difficulties when applying the sprays and when counting the drops; the latter must be done by noting the loss from the limb instead of by the simpler method of collecting those on the ground. It has the advantage that each treatment can be represented on every tree, and the tree thus becomes the "experimental block."

B. RECORDS OF RESULTS AND OTHER PARTICULARS

The usual method of determining the number of drops has been to remove those already under each tree at the start of the experiment and to collect and count the subsequent drops; this method has the advantage that no fruit need be counted more than once. Often the drops collected at the start have been counted so as to provide some measure of the initial dropping tendency of the different trees. Where the various limbs on the same tree have received different treatments, their respective drops tend to become mixed up when they reach the ground. It has been usual, therefore, either to "tag" the fruits at the start, or to determine the numbers dropped by counting the numbers left on the limbs. Both these methods involve increased labour.

The final number of fruits picked has usually been determined by counting, or estimated by sampling, and the initial number, present at the start of the experiment, calculated by summing the numbers of drops and picked. Sometimes it has not been found practicable to determine the numbers of picked fruit or calculate the initial numbers.

Other particulars, such as mean weight, colour and keeping quality of the fruit, have been provided by some workers. Most investigators have recorded the age of the trees and several the cultural conditions. Some have given particulars about weather conditions, especially the temperatures prevailing at the time of, and after, spraying.

C. PRESENTATION AND INTERPRETATION OF RESULTS

Most investigators have expressed their results as accumulated percentage drops in terms of the initial numbers of fruit on the trees. Some (Roberts and Struckmeyer, 1943, Vyvyan, 1941 and 1942), have preferred to use the residual percentages left on the trees. Obviously either value can easily be obtained from the other by subtraction from 100. Often successive values of the percentages have been given for a series of dates. The object of using percentages rather than the actual numbers of drops is to eliminate variability directly due to differences in initial size of crop. For example, other conditions being equal, we would expect a tree bearing 2,000 fruits to drop twice as many as one bearing only 1,000. Where the final number of fruits picked has not been determined and the initial numbers cannot be calculated, the actual numbers of drops have sometimes been given. Some investigators, however, have preferred to express the numbers dropped after treatment as percentages of those dropped before treatment. Southwick (1942) points out that "This method of calculation takes into consideration the natural dropping tendencies of trees which do vary greatly." Batjer (1943) has likewise pointed out that "trees receiving the same treatment commonly vary greatly in fruit drop" and that "until a more accurate measure of results than counting fruit drops is evolved" the differences between treatments must be large before we can be sure they are real.

Trees bearing a heavy crop sometimes seem to drop a larger proportion of their fruits than trees bearing a light crop—probably owing to greater competition between the fruits. Where trees are of the same size, and initial number of fruits is therefore a measure of the relative crop, a more accurate measure of results might be obtained by adjusting the numbers of drops by analysis of variance with the initial numbers, instead of using percentages; this method would take into account the indirect as well as the direct effects of differences in initial number of fruits.

From the practical standpoint the main information required is the net reduction in drop due to a treatment, and it is of little importance whether this reduction is due to direct or to indirect effects, or was achieved during the first week or some subsequent week after treatment. This information can be obtained from the accumulated percentage drops, and can be translated into pounds per tree or bushels per acre if the initial crop per tree and the number of trees per acre are known.

Sometimes, however, additional information is required. For example, Gardner, Marth and Batjer (1940), in one of their experiments (*95*), found that a number of the fruits were shaken off by a gale which occurred 15 days after the trees had been sprayed, and wished to determine whether the sprays had afforded any protection against the gale. By the time of the gale, the residual numbers on the sprayed and unsprayed trees had become considerably different owing to past effect of the sprays, they therefore expressed the drops during the gale as percentages of these residual numbers. This method of presenting the drops during a period, as a percentage of the residual number at the beginning of the period, has been used by other workers (Ruth and Powell, 1944, Burkholder and McCown, 1941, Batjer and Marth, 1941 and van Stuivenberg, 1941), and seems capable of extension where it is desired to distinguish between the effectiveness of a treatment during a period and the result of its effectiveness during past periods, as, for example, when it is required to know how long a spray material retains its power to produce effect. This method, however, suffers from a disability, for it involves the assumption that the denominator (residual number) remains constant throughout the period, and this is manifestly not the case if there is any drop at all. Much of this bias can be overcome by determining the residual numbers at the beginning and end of the period and using their mean value as the denominator when calculating the percentages. It is probably simpler, however, to use the equation (Vyvyan, 1946) :—

$$Q = 100\ (\log_{\epsilon} X_1 - \log_{\epsilon} X_2)/(t_2 - t_1)$$

where Q is the required index of rate of drop during the period (t_1 to t_2), X_1 is the residual number at the start of the period (t_1), X_2 the residual number at its end (t_2) and (t_2—t_1) the length of the period in days. Vyvyan (1941) used logarithms to the base 10, but in the later paper (1945) he uses natural logarithms (to base ϵ) as the values of the index are then the true rates of drop on the compound interest basis.

The same author (Vyvyan, 1946) calculated the " percentage effect " of a spray during a period by the use of the equation :—

$$q = 100\ (Q_C - Q_S)/Q_C$$

where Q_C and Q_S are the rates of dropping in the control and sprayed trees, and q the required index of effect. He pointed out that this index suffered from certain disabilities and is only an approximation.

Part 4

EFFECT OF GROWTH SUBSTANCES ON PRE-HARVEST DROP

This part of the paper deals with the control of pre-harvest drop by the use of growth substances. After a brief tribute to the pioneer work of Gardner, Marth and Batjer, the various aspects of the problem, such as varietal differences in response, are dealt with in successive sections.

The main results published by the various workers are summarized in Table 5, at the end of this paper. This table does not claim to be exhaustive, for some publications have not been available owing to war conditions and others may have been overlooked for the same reason, but an attempt has been made to make the table as representative as possible. Considerable condensation has been necessary, for some of the original tables give data for several treatments and for a number of successive dates. To economise space, the values for only a few treatments and a few dates are given, but further details, where important, are provided in Tables 1 to 4, or in the text. The experiments summarized in Table 5 are arranged alphabetically under varieties, starting with apples, and are given serial numbers. Wherever a particular experiment is referred to, either in another table or in the text, the appropriate serial number is given in *italics*. For cross-reference, the last column of Table 5 gives the tables and pages of the text where further information or comments may be found.

A. PIONEER WORK OF GARDNER, MARTH AND BATJER

Special mention must be made of the work of Gardner, Marth and Batjer (1939 and 1940), which was so successful that this method of controlling drop became at once a practical proposition. The work was so comprehensive that subsequent investigations have been largely supplementary rather than concerned with new ideas. Their various results are described under the appropriate headings in the paragraphs that follow ; all that need be given here is an outline of the scope of their work. They confined their experiments to the apple and found considerable varietal differences in degree and duration of response. They tried a number of different growth substances and found two " particularly effective with all the varieties . . . treated." They demonstrated the very low concentrations required, the best time of application and the very localized nature of the effect. They also tried the effect of adding oil, spreaders and other substances to the growth substance sprays. The results of the numerous experiments reported since by other workers have, in the main, confirmed their findings and extended them to certain other kinds of fruit, such as the pear, and to other localities and climates.

B. VARIETAL DIFFERENCES IN RESPONSE

Gardner, Marth and Batjer (1940) carried out thirty experiments on twenty-one different varieties of apple and found that all " responded to a marked degree by delay in fruit abscission when sprayed with growth substance," but they found that the degree of response varied considerably with the variety. The existence of these varietal differences has been repeatedly confirmed (*see* Table 5) by later work on the apple, and there are indications that they exist also in other kinds of fruit, such as the peach (Hesse and Davey, 1943). In the apple, certain varieties, such as Williams Early Red and Delicious, seem always to show a remarkable reduction in drop when treated, but others, such as Grimes Golden, rarely show any response.

Varietal differences in response may be due to several factors. Gardner *et al* (1940) suggest that they are due in part " to the readiness with which the fruit pedicel of the variety can be hit with the spray, and also to the characteristic of long stemmed fruits to hang down so that the cavities retain more of the spray." They name Williams, Winesap, Rome Beauty and Delicious as varieties having this characteristic. On the other hand, " in McIntosh and York Imperial the pedicels are so short and stiff that most of the fruit are tilted in their attachment." Here the pedicels are harder to hit and the spray would tend to drain off. Number

of fruit borne on the spur is another factor that might work in the same way ; Bramley Seedling, for example, frequently carries two, and these become so tightly pressed against one another that it must be very difficult for the spray to reach their pedicels. Moreover, there is a tendency for fruits borne in cluster to push one another off as they increase in size (Whittaker *et al*, 1944) and there seems to be no reason why sprays should reduce drop due to this cause, as an abscission layer is not necessarily involved. Perhaps the reason why pears sometimes respond so well to the sprays is the readiness with which their pedicels can be wetted.

Another factor concerned seems to be the time at which the variety matures its fruit. Blair (1940), for example, found that " In general the sprays were more effective with summer than fall varieties." Batjer (1942a) and Southwick *et al* (1941b) make the same observation. There are, however, certain important exceptions to this rule, e.g., Delicious. Possibly this relative lack of response in late varieties is due in part to low temperature conditions at the time when maturity is developed, or a lower physiological activity of the tissues (Batjer and Marth, 1941). It has been mentioned above, that growth in early maturing varieties appears to continue at a uniform, high rate up to harvest time, but in late varieties it may be slower and decline.

Results with stone fruit have not proved very promising (Batjer, 1943). Hesse and Davey (1943) got good control with the Stewart apricot in one season (*144*) but little in another (*145*). They had little success with the Elberta peach (*146, 147*).

Asami (1941) has reported some success with a variety of persimmon.

C. PART OF PLANT AFFECTED

Gardner, Marth and Batjer (1940), in one of their initial experiments, tried the effect of spraying fruit of the Delicious apple (*20*) with alpha naphthaleneacetic acid at the stem end only and the calyx end only. No spray was allowed to go on to the leaves. They got some slight response from the spray on the calyx end but very much more response when only the stem end (fruit pedicel and cluster base) were sprayed. The accumulated percentage drops after three weeks were 17%, 76% and 93% respectively from the stem end, calyx end and unsprayed fruit. Experiments of this type do not seem to have been carried out on other kinds of fruit or with other spray materials, but there seems no reason to expect that they would yield different results. These authors stated that " The importance of the leaves transmitting any spray stimulus to the fruit stem has not been adequately investigated " and stress the difficulty of wetting the leaves without wetting the fruit also, but they considered that " The lack of transmission of effect to fruit only short distances away from sprayed leaves . . . suggests that leaf coverage is not particularly important." These authors, however, did get some slight effect from applying the growth substance to the soil round the roots, which suggests that a slight translocation of the substance from the roots to the fruit may be possible. Injection experiments gave no results. Overholser *et al* (1943), in some small-scale experiments on Grimes and Jonathan (*48*), applied the growth substance to fruits alone and got less response than when the entire tree was sprayed. They suggest that " this may indicate that the material is absorbed not only through the stems of the fruit but also through the leaves."

D. RELATIVE EFFECT OF DIFFERENT SUBSTANCES

Gardner and his collaborators (1939 and 1940) compared the effect of naphthaleneacetic acid with those of various indole derivatives, in an experiment with the apple variety King David (*51*). In round numbers, the percentage drops under these various treatments were : naphthaleneacetic acid 11% ; indolebutyric and indoleacetic acids, each 34% ; indolepropionic acid 45% ; unsprayed controls 53%. Thus the naphthaleneacetic acid spray proved very effective, two of the indole derivatives had little effect and the third even less. They report that similar results were obtained with the apple variety Wealthy. Few trees were used in these experiments ; each material was sprayed on individual branches of the same tree, and, in the case of King David, only three or four branches received each treatment. No further work with indole derivatives seems to have been reported by any worker, and indeed, no useful purpose would be served by using these materials unless their greater cost could be offset by equal effect at lower concentrations.

Examination of Table 5, at the end of this paper, shows that most workers have used either naphthaleneacetic acid (NAA), naphthalene acetamide (NA), or the sodium or potassium salt of the acid (NaNA or KNA). The commercial preparations (C.P.), whether unnamed or named (Ap-L-Set, Fruitone, Phyomone, Parmone, Stafast or Stop Drop), seem all to contain one or more of these three substances as the active ingredient.

The main experiments, where pure chemicals have been used and two or more substances have been compared, are summarized in Table 1. Gardner *et al* (1940) compared the effect of naphthaleneacetic acid (NAA) with those of its sodium, potassium, calcium and ammonium salts, in an experiment with Gallia Beauty ; they do not give the values, but they found that the salts were all " equally as effective as the acid itself." In preparing these salts, " an equivalent amount of the respective cation was added as the hydroxide." Hoffman (1941b), using the sodium salt, got similar results with Williams Early Red (*115*), Wealthy (*106*) and McIntosh (*66*) and (*67*), but Batjer and Marth (1941) thought the effect of this salt wore off sooner than that of the acid, in an experiment on Delicious (*15*). Ruth and Powell (1944) got good control in Delicious (*29*) with the potassium salt.

Numerous comparisons have been made between naphthaleneacetic acid and naphthalene acetamide (*vide* Table 1). The acetamide was thought the more effective by Gardner *et al* (1940) (*31*), (*34*), (*105*) and Murneek (1940) (*24*) and (*120*) on apple varieties and by Davey and Hesse (1943) (*139*) working with a pear ; the acid the more effective by Enzie and Schneider (1941) (*99*), working with apples. Some authors consider the two substances equally effective (e.g., Hoffman, 1941a (*63*), and 1941b (*114*), Ellenwood and Howlett, 1942, and Southwick and Shaw, 1941b). Gardner (1940), though considering the acetamide slightly the better, found their relative effects so similar that it was difficult to be sure that any real difference existed. In general, it seems that for true " pre-harvest sprays," put on after all active shoot growth has ceased, there is little to choose between the acid and the acetamide. For early sprays, put on when young leaves and stems are present, the acetamide is to be preferred, as it does not cause the twisting and distortion that sometimes follows an application of the acid.

All the chemicals so far mentioned were used, in their pure form, by Gardner, Marth and Batjer (1940) in their original experiments in 1939. These authors also used the ethyl and methyl esters of a-naphthaleneacetic acid in an experiment on Rome Beauty (*95*). They found that these esters were " appreciably less effective than the acid itself." They considered that this could not be accounted for by their " slightly lower molar concentration . . . due to their slightly greater molecular weight."

Gardner (1940) thought that " in all probability, more effective compounds . . . and perhaps better method of application or of increasing the effectiveness of the ingredients " would be found, but up to the present few new materials seem to have been tried or to have shown much promise. Hitchcock and Zimmerman (1941) tried naphthoxyacetic acid and naphthoxyacetamide, because the former had proved " effective for inducing other hormone-like responses similar to those caused by naphthaleneacetic acid," e.g., " delayed abscission of flowers and petiolar stubs in tomato." Their experiments were on a small scale and their results inconclusive owing, perhaps, to variability in the material. They considered, however, that these substances should be effective if used at the correct strength. Batjer and Marth (1941) (*110*) and Swarbrick (1943) (*1*) and (*37*) and (1945) (*125*) have tried naphthoxyacetic acid, however, and found it less effective than naphthaleneacetic acid (*vide* Table 1). Batjer and Marth (1941) tested Tetralin-6-acetamide on the apple varieties Williams (*110*) and Delicious (*15*). With Williams this substance was less effective at 20 parts per million than naphthaleneacetic acid at 5 parts per million, but with Delicious the two substances used at concentrations of 10 and 100 parts per million respectively, proved equally effective. These same authors also tested alpha-naphthalene acetonitrite, naphthalene methyl thiocyanate and isothiocyanate, and sodium thiocyanate—substances reputed to enhance fruit colour—in their experiment on Williams (*110*), and found they neither decreased fruit drop when used alone, nor increased it when used with naphthaleneacetic acid or the acetamide. Kadow and Hopperstead (1942) seem to have obtained good results in some preliminary trials with " beta-1-naphthoxyl propionic acid," but no further work with this substance seems to have been reported.

Table 1.—Relative effect of various growth substances.

Serial number as in Table 5	VARIETY	Period in Days.	*Accumulated percentage drops.*							p.p.m.	REMARKS
			Un-sprayed	Sprayed with							
				NAA	NA	NaNA KNA	NOA	T6A	DPOA		
1	ALLINGTON	25	16	8			11			10	
8	BRAMLEY	17	9	4	4					6	
15	DELICIOUS	16	17	6		7		*5**	-	5	*100 p.p.m.
24	,,	9	39	7	1					10	
31	DUCHESS of OLDENBURG	7	68	27 19 18	29 19 13					10 10 20	G.S. alone +1% oil +L.A. + Lime.
34	EARLY McINTOSH	12	78	14 5	13 0					2½ 5	
37	EDWARD VII	25	9	9			9			10	
63	McINTOSH	8/9	20	3	3					5	
66	,,	7	13	2*		1				10	*mean for 2 preps
67	,,	6	24	8*		8					*mean for 2 preps.
99	STAYMAN WINESAP	13	15	5	6					10	
105	U.S.D.A.9.	7	80	40 12	31 22					2½ 5	
106	WEALTHY	9	28	9*		8				5	*mean for 3 preps.
110	WILLIAMS EARLY RED	9	44	2	2		42	18		10 20	
114	,,	10	74	½*	1					10	*mean for 3 preps.
115	,,	7	56	1		1*				10	NaNA
119	WINESAP	15 23	35 60	5* 3** 36* 16**					11 19	10 10 10	*NAA alone **NAA +0.5 Carbowax
120	,,	23	33	7	10					10	
125	WORCESTER	35	80	45				84	78	20	
139	WILLIAMS (Pear)	16	*198*	*135*	*73*					10	*numbers* per tree
144	STEWART (Apricot).	35*	25	8	11					10	*2nd spray on 11th day.

Explanations.—The *Accumulated percentage drops* are the total drops during the period of observation expressed as a percentage of the number of fruits present on the tree at the start of the period. This period started on the day of spraying except in Nos *8* and *99*, when recording of drops began 1 and 2 days later respectively. *Substance* NAA= a-naphthaleneacetic acid ; NA = a-naphthalene acetamide ; NaNA KNA=sodium or potassium salt of the acid ; NOA =naphthoxyacetic acid ; T6A=Tetralin-6-acetamide ; DPOA=2-4-dichloro-phenoxyacetic acid. *p.p.m.*=parts per million (1 p.p.m. = 0.0001 percent.)

Swarbrick (1945) found 2-4-dichloro-phenoxy-acetic acid ineffective with Worcester (*125*), but Batjer and Marth (1945) have obtained promising results with this substance in an experiment with Winesap (*119*). They found it less effective than alpha-naphthaleneacetic acid during the first fortnight after application but more effective during subsequent weeks. They suggest that it might be worth while trying a spray containing both substances ; alpha-naphthaleneacetic acid to control the drop during the first few weeks and 2-4-dichloro-phenoxy-acetic acid to maintain the control in later weeks. Further work with this substance seems desirable, especially in the case of varieties which do not respond well, or respond for only a short period, to the more usual substances. It is not so much a more active substance than the normal naphthalene derivatives that is required as one that will maintain its activity for a longer period.

With most varieties nothing better than naphthaleneacetic acid or the acetamide seems to be required.

A number of commercial products to control fruit drop have been put on the market ; their active ingredients seem to be usually, if not always, either naphthalene acetamide or naphthaleneacetic acid or one of its salts. Several authors have compared certain of these products with one another or with the pure chemicals and, in general, little or no differences in effectiveness have been found between them. For example, Greve and Kadow (1941) got good results with the apple varieties Delicious (*21*), Grimes Golden (*42*), and Stayman Winesap (*101*), from sprays of Parmone, Fruitone, Stop-Drop and App-L-Set. The last named was not tried on the variety Williams (*113*), but the other three were used with success. Murphy (1941), however, got poor control of drop in the apple variety Baldwin (*3*) with these four products, but the pure chemical naphthaleneacetic acid proved equally ineffective and the author attributed the failure in each case to the spray being applied too late. Petch (1940) has reported good results with Parmone, Fruitone and Stop-Drop with several apple varieties. Hesse and Davey (1943) got only slight reduction of drop in the Elberta peach (*146*) and (*147*) with Fruitone, Parmone and pure naphthaleneacetic acid, but the same authors (Davey and Hesse, 1943), working with Bartlett pear (*139*) and (*140*), got good results with Fruitone and naphthaleneacetic acid but better control with the acetamide. Hilton and Spur (1943) found Parmone and Phyomone effective with Gravenstein (*41*) and McIntosh (*61*) in Nova Scotia in 1942, but trials of Parmone and Stafast on the same varieties in 1943 were spoilt by the weather (Hilton, 1944) (*62*). Several workers have reported success with commercial products but have not specified which they used. Most growers will probably find it cheaper and more convenient to use one of these commercial preparations rather than the pure chemicals, which are usually difficult to handle and dissolve.

E. EFFECT OF CONCENTRATION

One of the characteristics of pre-harvest " anti-drop " sprays is the very low concentration of growth substance required. That usually recommended is 10 parts per million (0·001%), and this is often called the " standard " strength.

In many of the experiments reported only one concentration has been used ; in others, two or more have been compared. Those used, or found most effective, are shown in the column headed " p.p.m." (parts per million) in Table 5, and the relative effects of different concentrations, where more than one has been used, are shown in Table 2. The usual concentrations have been 10 p.p.m. or 5 p.p.m., but stronger or weaker sprays have sometimes been tried.

The lowest concentration that seems to have been tried is 1 part per million, i.e., 1/10th standard strength. This was used by Gardner, Marth and Batjer (1940), who report that it resulted in an " appreciable reduction " in drop. McCown and Burkholder (1940), however, obtained no material effect with this concentration in experiments with Rome, Winesap and Golden Delicious ; they obtained a significant reduction in Delicious, when the eastern halves of the trees were sprayed and the western halves unsprayed, but were " inclined to attribute the difference " chiefly " to weather conditions " as similar differences in drop were found in the corresponding halves of unsprayed trees. These experiments are not shown in Tables 2 and 5.

Concentrations of $1\frac{1}{4}$, $2\frac{1}{2}$ and 5 p.p.m. have been compared by Batjer (1942b) in an experiment with Williams Early Red (*111*). When the sprays were applied at a low temperature

(63° F.) in the early morning, the reduction in drop was more or less proportional to the concentration, the values being : 1¼ p.p.m. 4·8%, 2½ p.p.m. 3·7%, and 5 p.p.m. 1·8%. But when applied at a higher temperature (83° F.) in the heat of the day, the two higher concentrations proved equally effective ; the values being 3·5%, 1·7% and 1·8% respectively. Unsprayed trees showed 13% drop.

Concentrations of 2½ and 5 p.p.m. have been compared by a few investigators. The higher concentration seems to have been much more effective with Early McIntosh (*34*) and U.S.D.A.9 (*105*) and slightly more effective with Delicious (*15*), (*16*) and (*25*), but to have had little, or no, additional effect with Beauty of Bath (*5*), McIntosh (*56*), (*57*) and (*58*), Winesap (*122*), and Worcester (*126*). In a few of these experiments (*15*), (*25*), (*56*), (*57*) and (*122*), a spray of 10 p.p.m. was included, and in every case seems to have given improved control. In fact, increase in concentration from 5 or 6 p.p.m. to 10 p.p.m. appears to have had more effect than the increase from 2½ to 5 p.p.m., or from 3 to 6 p.p.m. Concentrations of 10 p.p.m. and 5 p.p.m. have been compared in several experiments. In some the stronger spray seemed decidedly the better (*24*), (*80*c) and (*107*), in others slightly better (*21*), (*36*), (*59*), (*60*), (*72*), (*80*a) and (*96*), or without additional effect (*45*), (*63*), (*69*), (*76*), (*87*), (*101*) and (*110*).

In many experiments only one concentration has been used ; here it is not possible to know whether a weaker spray would have given as good control or a stronger spray a better control. Good control by commercial sprays used at quarter standard strength (2½ p.p.m.) has been reported by Roberts and Struckmeyer (1943) (*90*) and (*91*) and by Kadow and Hopperstead (1942) (*118*). Vyvyan (1943) got good control in Conference pear (*134*) with a spray at 4 p.p.m. Sprays of 5 p.p.m. have been used with success by Murneek (1940a) on Delicious (*23*), by Gardner, Marth and Batjer (1940) on Delicious (*19*), King David (*51*), Rome Beauty (*95*) and York Imperial (*130*), by Hoffman (1941b) on Wealthy (*106*) and by Kadow and Hopperstead (1942) on Williams (*117*). Overholser and his collaborators (1943) got good control in the Bosc pear (*132*), but little in the apple Jonathan (*48*). Vyvyan (1946) obtained only moderate control in Bramley's Seedling with sprays of 7½ p.p.m. (*9*) and 6 p.p.m. (*8*), but a spray at 10 p.p.m. was even less effective (*10*).

Trials with sprays of 10 p.p.m. have been too numerous to be described here in detail, but examination of the values in Table 5, shows that very good control of drop has often been secured, especially with certain varieties such as Delicious, Duchess and Williams Early Red, and good to fair control with most varieties.

Sprays of above " standard " (10 p.p.m.) strength have been tried by some investigators. Gardner, Marth and Batjer (1939) began by using them but later considered them unnecessary. Southwick and Shaw (1941a) reported that " in one test on Baldwin, using a 10 part per million spray and one higher, the latter seemed more effective " and suggested that concentrations above 10 p.p.m. will probably be necessary with some varieties, possibly including McIntosh, to obtain the control desired. Southwick (1943), in a test with Wealthy (*108*), found " control of drop was correlated with spray concentration even up to a 40 part per million level." " The differences were striking and easily discernible in the orchard to impartial observers. The fruit . . . with the stronger sprays not only hung on better and longer but was much more highly coloured." With McIntosh (*84*), too, the 20 p.p.m. spray was " somewhat more effective than " the standard 10 p.p.m. spray. Strickland and his collaborators (1941) used 20 p.p.m. (*49*), (*92*) and (*142*) and Swarbrick (1945) used 15 p.p.m. (*4*) and 20 p.p.m. (*125*), in each case with marked success, but it is possible that lower concentrations, if they had been used, might have given sufficient control.

The evidence on the effect of concentration is thus somewhat conflicting ; in general an increase in concentration resulted in an increase in the control of drop. Adequate control, however, has sometimes been got with low concentrations, such as 2½ or 5 p.p.m., and the further reduction resulting from the use of stronger sprays has not been sufficient to justify their greater cost. Obviously it is the amount of the active ingredient that reaches and is retained at the reactive region that is important and various varietal and environmental factors will influence this amount.

Table 2.—Effect of concentration of growth substance.

Serial number as in Table 5	VARIETY	Period in Days	G.S.	*Accumulated percentage drops.* Concentration (p.p.m.) 0*	2½	5	10	20	Remarks. *Control
5	BEAUTY OF BATH	7	NAA	63	50	56			sprayed too late.
15	DELICIOUS	16	NAA	17	7	6*	4		light appln. gave 8% drop
16	,,	21	NAA	16	7	5			at 85°F.
21	,,	10	NAA	26		10	8		
24	,,	9	NAA	39		14	7		NA gave more control
		21	NAA	66		29	10		
25	,,	12	NAA	13	10*	9**	7		*=3 p.p.m., **6 p.p.m.
34	EARLY McINTOSH	12	NAA	78	14	5			
					13	0			
36	EDWARD VII	30	NAA	49		42	34		
45	JONATHAN	10	NAA	20		4	5		
56	McINTOSH	?	NAA	19	9	8	6		
57	,,	?	NAA	31	17	18	13		
58	,,	12	NAA	23	14	14			NAA used alone
					13	11			NAA + ½% oil.
59A	,,	15	NAA	20		16	14		
60	,,	7	C.P.*	19		11	8		*Fruitone & Parmone
63	,,	8–10	NAA	20		3	3		
69	,,	5	NAA	8		2	2		
72	,,	12*	NAA	28*		9*	7*		mean for 3 dates.
76	,,	12	NAA	15		7	7		
80A	,,	19	C.P.	16		14	12		
80B	,,	18	C.P.*	24	16		13		*+ oil
80C	,,	19	C.P.	19		7	4		
84	,,	10	C.P.	37		23	16	16	2 at 10 p.p.m. gave 8% drop
86	,,	12	NAA	18			9	4	
87	MILLERS SEEDLING	21	NAA	32		17	16		
96	STAYMAN WINESAP	35	NAA	39		16	15		
101	,, ,,	15–16	C.P.	27		12	12		
105	U.S.D.A.9.	7	NAA	80	40	12			
			NA		31	22			
107A	WEALTHY ..	16	NAA	37		31	22		
107B	,,	15	NAA	30		31	12		
108	,,	19	NAA	52				40	40 p.p.m. gave 16% drop.
110	WILLIAMS E. RED	9–13	NAA	44		1	2		
111	,, ,, ,,	11	NAA	13	2	2			at 83°F: 1¼ p.p.m. gave 4% drop
					4	2			at 63°F; 1¼ p.p.m. gave 5% drop.
122	WINESAP	19	NAA	17	9*	9**	2		*=3 p.p.m.; **=6p.p.m.
126	WORCESTER	22	NAA	14	5	7			
140	WILLIAMS (Pear)	28–42	NAA	20		13	13		+L.A. and oil.

Explanations.—The *Accumulated percentage drops* are the total drops during the period of observation expressed as a percentage of the number of fruits present on the tree at the start of the period. This period started on the day of spraying except in Nos. *45, 84* and *108,* when recording of drops began 2, 3 and 1 days later respectively.

In most cases it is probably best to use the standard strength of 10 p.p.m. Weaker sprays, such as 5 p.p.m., are possibly sufficient for certain varieties, e.g., Williams Early Red and Delicious, provided the sprays are applied on a hot day. On the other hand, with difficult varieties, such as McIntosh, concentrations of 15 to 20 p.p.m. may be worth while, especially in cool weather. Too high concentrations, however, may be a disadvantage, apart from their greater expense; Batjer (1941) suggests that sprays of over 10 p.p.m. are "likely to make the fruit stick on so tightly that difficulty will be encountered in picking, since spurs may be broken off or stems pulled from the fruit."

F. EFFECT OF WEATHER CONDITIONS

Both the weather conditions at the time of spraying, and those incident up to the time of harvest, seem sometimes to have considerable effect on the magnitude of the response.

Temperature at the time of spraying seems to be important, possibly because high temperatures may result in more rapid drying and therefore less dripping and a greater deposit of the growth substance. Batjer (1942b), for instance, sprayed trees of Williams (*111*) at 1 p.m. (Temp. 83° F.) and at 5 a.m. (Temp. 63° F.). There was less drop with the mid-day spray. At the lower temperature the control was increased by higher concentrations of the spray. The same was found for Delicious (*16*); here "A concentration of 2·5 p.p.m. at 64° F. proved to be no better than the unsprayed treatment, while the same concentration at 84° F. was just as effective as 5 p.p.m. at 64° F." He got the same results for Winesap in one experiment, but not in another. He suggests that the results indicate the value of using higher concentrations on days, or portions of days, when the temperature is low, and of making the applications during the warmer part of the day when only a limited amount of spraying is to be done. "The early-mornings generally required about 1 hour to become dry, as compared with less than 30 minutes for the mid-day sprays. The greater effectiveness of the latter suggests that absorption of the . . . solution was greater at the higher temperature despite the fact that the spray film became dry within 30 minutes." He thought differences in suction tension of the tissues might account for "some of the differences obtained," but reports that "limited suction tension measurements with apple have indicated even a greater negative pressure in early morning than later in the day." Overholser *et al* (1943) has reported somewhat similar results from spraying Delicious (*27*) at 7 a.m. (Temp. 42° F.), 1 p.m. (Temp. 75° F.) and 7 p.m. (Temp. 61° F.). The percentage drops were 6·2%, 3·3% and 5·2% respectively; that from the controls 25·4%. Only a few trees, however, were involved. He also obtained better control with this variety in the years 1940 and 1942, when the temperatures at the time of spraying, and for the next four hours, were high, than in 1941, when the corresponding temperatures were low. Ruth and Powell (1944) also found evidence that temperature at time of application is important. Hilton (1944) put his sprays on McIntosh in 1943 during cool weather and attributed his failure to obtain control that season largely to this fact. At the other extreme, Roberts *et al* (1943) used App-L-Set at $\frac{1}{4}$ lb. per 100 gallons during an exceptionally cold spell in 1942. Maximum temperatures seem to have been below 50° F. and minimum well below freezing. The apple variety Snow, sprayed on September 24th when the maximum temperature was only 43° F., dropped only 20% by October 12th, while the control dropped 97%. He got somewhat similar results with even later sprays on Spy (*90*) and (*91*). He concludes that "this season's results clearly indicate the practicability of spraying after a 'freeze,' and also that spraying was efficient this year when applied during a period of low temperature."

The temperatures incident during the period between spraying and picking seem to influence the duration rather than the intensity of spray effect. According to Gardner (1940), "it is believed that temperature does not seriously affect the net results of the spray applications since the rate of normal drop is also slowed down by low temperature."

Rain may be harmful if it falls before the spray has had time to dry. Southwick (1943) in an experiment on McIntosh (*84*) found that one of the spray treatments had little effect and suggested that this might have been due to an onset of steady rain which occurred before this particular spray was dry. van Stuivenberg (1941) used sprays of various concentrations on

trees of the apple Sterappel (*102*) and (*103*) on the 9th and 10th September, 1940, and got poor results which he attributes to a spell of very wet and windy weather which set in soon after spraying on the 10th. Later sprays on the same trees were followed by more favourable weather conditions and gave better control of drop. Overholser and his collaborators (1943) in an experiment on Delicious (*28*), made water applications simulating rain 2 hours, 8 hours and 24 hours after the application of a growth substance spray. The number of replicates was rather low, but the results indicated that " the only serious decrease . . . occurred when the water spray was applied 2 hours after the alpha naphthalene acetic acid spray."

The effect of strong winds at the time of spraying with growth substances does not seem to have been studied much ; obviously such weather conditions will be avoided if possible. Swarbrick (1945) has reported that such a wind was " responsible for certain irregularities in results " in an experiment with the apple Worcester (*125*). There are other indications (Steer and Moore, 1941) that drift, due to wind, on to parts already sprayed or about to be sprayed, may lead to local increase in deposit. Wind may also increase the rapidity of drying. Evidence of the power of sprays to prevent drop in heavy winds is somewhat conflicting. The velocity of the wind must clearly be a factor, and the time when it occurs relative to the time of the application of the spray seems to be important. Gardner and his collaborators (1940) found that certain treatments afforded protection against a gale that occurred 15 days after spraying (*95*). van Stuivenberg (1941) has reported good control in the pear St. Remy (*136*) with a spray at 10 p.p.m. in spite of a heavy gale that occurred about a fortnight after spraying. Hoffman and his collaborators (1942) found a spray at the same strength effectively controlled drop in Northern Spy (*89*) during a gale which occurred a week after spraying. Vyvyan (1945) reports similar control during a gale by a spray of the same strength on Beauty of Bath (*6*). Berry and Swarbrick (1942), however, found that a 50 mile per hour gale, occurring four weeks after one application of a growth substance spray and four days after a second, brought down half the crop of the apple variety Edward VII (*36*), though up to that time there had been little drop from sprayed or control trees. They remark that " It was unfortunate that the gale occurred just when the effect of the first spray was wearing off and before the second application had had time to take effect." Further evidence, however (Swarbrick, 1943) (*37*), seems to suggest that Edward VII is a variety that does not respond well to growth substance sprays. Hilton (1944) suffered a similar disaster with his McIntosh (*62*) experiments in 1943 ; he reports " The results of the Kentville trials in 1943 have been disappointing. This is chiefly as the result of two heavy windstorms that dropped more than 80% of the crop on the experimental trees." " In most cases, the spray treatments show slightly less drop than the check units, but the differences are too small to prove any significance."

G. DURATION OF EFFECT

According to Gardner *et al* (1940), " The effect . . . on most varieties usually reaches a peak in five or six days and may continue quite effective for two or three weeks, varying somewhat with the concentration and considerably with the variety, after which . . . the effect is rather quickly dissipated."

The time required before effect becomes appreciable seems to vary considerably. Some authorities seem to have detected a reduction in drop by the end of the first day. Whittaker *et al* (1944), on the other hand, working in Australia with the apple variety Jonathan (*50*), found in a " particular instance the sprays had little effect up to the seven-day period, but from then on their influence was very noticeable." According to their data, however, the total drop during the first week was very small—about 1·2% from the sprayed and about 0·9% from the controls. Hesse *et al* (1943), working with the Stewart apricot (*144*) and (*145*), found a similar long delay in the time " necessary for the spray to become effective in stopping the drop. Under the various conditions of the experiments a period of one week to ten days elapsed before a response was noticed." The time seems usually to be intermediate between these extremes and is probably largely influenced by weather conditions.

The duration of the effective period seems to vary considerably and to be influenced by a number of factors. Moreover, it is not always easy to estimate the duration from data presented in the usual form—the accumulated percentage drops on the basis of initial crop.

These values are ideal for showing the net effect of the sprays *up to* a given date, but suffer certain disqualifications when effect *at* a particular date is required, for they take no account of differences in the residual numbers of fruit on the trees, and thus tend to underestimate the magnitude of the reduction in drop when large differences in residual number have arisen.

There seem to be considerable varietal differences in duration of response. Gardner *et al* (1940) found that the apple variety McIntosh was " in a class to itself " ; here the effect of spraying diminished " rather abruptly after eight or nine days," though it might be prolonged somewhat if low temperatures prevailed. With some varieties, however, the effect persisted " for rather extended periods " ; for example, some " Stayman Winesap trees, sprayed . . . four weeks before normal harvest time, dropped only half as many fruit as the unsprayed." Southwick and Shaw (1941b) found that Wealthy behaved like McIntosh in having only a short period of response, and Hilton and Spurr (1943) seem to have found the same in Gravenstein (*41*). On the other hand, the period is much longer with some varieties ; with Williams Early Red, for example, Batjer (1942a) reports that " The sprays so completely control dropping . . . that the early-maturing fruit remains on the tree more or less indefinitely." Here the danger is over-maturity, if they are not picked at the proper time. Swarbrick (1945) found some fruit remained on certain sprayed trees of Beauty of Bath (*4*) for more than five weeks, became over-ripe and split open into clefts ; when they ultimately fell, their stems were usually left adhering to the tree without the formation of the normal abscission layer. These trees, however, had received rather a high concentration of spray—·0015%.

Burkholder and McCown (1941) have suggested one possible reason for varietal differences in the duration of response, " The fact that varieties in which the initiation of abscission in bark tissues generally precedes pith abscission respond more readily to harvest sprays indicates an important relationship between mode of abscission and reaction to the effectiveness of these sprays." Many other authorities seem to support this interesting hypothesis, but it will probably be wise to wait till the abscission process has been examined in a larger range of varieties, and compared in each with duration of response to sprays, before accepting this relation as a rule.

Weather conditions, especially temperature, seem important ; for example, Gardner (1940), referring to McIntosh, states " Temperature plays some part also in the time required for the spray to take worthwhile effect . . . With high temperatures 24 to 48 hours may be sufficient but with relatively low temperatures four or five days may elapse before appreciable effect becomes operative . . . The somewhat prolonged effect at low temperatures may be only an apparent one consisting in an initial lag in starting." More recent work by other authorities seems to be in complete accord with this conclusion.

The same author, Gardner (1940), thought he got some increase in duration with higher concentrations of growth substance and by adding oil to the solution, but the increase was not large, and few workers seem to have found that either the composition of the spray or its concentration has much effect on duration of response, though both may influence the magnitude of the effect.

The recent work of Batjer and Marth (1945) with 2-4-dichloro-phenoxy-acetic acid (*119*) on Winesap is an outstanding exception. These authors also prolonged the duration of the effect of alpha-naphthaleneacetic acid on drop in this variety by the addition of Carbowax to the spray.

The rather limited duration of the period of response is clearly important when considering the best time for applying the sprays.

H. TIME OF APPLICATION

1. IMPORTANCE OF CORRECT TIMING

Batjer (1942a) has stated that " Timing is probably the most important single factor in the success of harvest sprays." Many other authors have also emphasised the great importance of this factor, especially in the case of a variety, like McIntosh, showing a short period of response.

A few investigators have carried out experiments especially designed to determine the best time for spraying, others have drawn conclusions on this matter from experiments planned for other purposes.

In calculating the net reduction in drop in experiments involving more than one time of application, the accumulated percentage drops should be based on the initial crop present at the time of the first application. For if the percentages are based on the residual numbers of fruit present at the time of the respective applications, and dropping has occurred in the intervals, the apparent reductions resulting from the later applications will tend to be exaggerated.

Among experiments specially designed to show the best time for spraying may be mentioned that by Batjer and Marth (1941) on Stayman Winesap (*96*). Here a-naphthaleneacetic acid was applied on two dates, September 11th and 20th, which were respectively 11 and 2 days before dropping began and 35 and 26 days before the normal harvest date. Two concentrations, ·0.05% and ·001%, were tried on each occasion. By October 18th the later spray was "considerably more effective." "While the data show a relatively long period of effectiveness in the case of this variety, they indicate that spray applications should not be made too far ahead of the harvest for best results."

Another experiment has been described by Murphy (1942); here three groups of McIntosh (*72*) were sprayed, each group on a different date—September 9th, 11th and 13th. A fourth group was left unsprayed. The accumulated percentage drop during the 12 days following the date of each application was determined and it was found that, "The percentage fruit drop from the September 9th application was significantly less than the drop from the two later applications." In each case the percentage drop was much less from sprayed than from unsprayed trees.

Gardner *et al* (1940) have described two experiments with McIntosh (*59a*) and (*59b*). In the one, spray was applied on September 6th and the accumulated percentage drops up to September 21st were 13·8 and 20·4 respectively for sprayed and control trees. In the other experiment, carried out on similar trees in the same orchard, the spray was applied on September 15th, and the percentage drops up to September 21st were 3·1 and 21·5 respectively. Thus the values for the control trees were about the same in each case, but the later spray gave the better control.

Where only one time of application has been tried and the control has been good, it is legitimate to conclude that the timing has been approximately correct. But when the control has been poor, the conclusion that wrong timing was responsible for failure must be, to some extent, a matter of conjecture. A large number of experiments of this type are on record, and the tentative conclusions that have been drawn from them all seem to support the view that correct timing is very important.

2. EFFECT OF EARLY APPLICATIONS

Very early applications do not seem to have had much effect. Gardner (1940) found that applications of naphthaleneacetic acid and naphthalene acetamide, applied at petal fall, failed to show any effect on the abscission of either blossoms or of young pollinated fruits in McIntosh, Yellow Transparent or Rome Beauty. Early applications of the same substances at the high concentrations of ·01%, and ·005% at "calyx spray" time, gave a noticeable reduction in drop in the early variety Yellow Transparent, which ripened and began to drop its fruit in early July, but had no apparent effect on the later ripening varieties McIntosh and Rome Beauty. "The effect, even from high concentrations . . . apparently did not persist for that extended time." Applied at this early date, the acid caused marked twisting and distortion of young shoots and leaves, the acetamide none. It is interesting to note that these substances applied at blossom time, cause an increase in blossom drop. In fact they have been used successfully as a means for thinning blossom (e.g., Burkholder and McCown, 1941).

Vyvyan (1946) sprayed some mature trees of Bramley Seedling (*9*) on June 21st, 1943, 100 days before picking date, with 7½ p.p.m. a-naphthaleneacetic acid. A relatively high rate of dropping during the first five days after spraying, followed by a lower rate which remained fairly constant until shortly before picking time, suggested that "June Drop" was still in progress at the time of spraying. The spray had very little effect, this may possibly have been due to lead arsenate which had been added to the spray solution.

The same author (Vyvyan, 1941) sprayed some 11-year-old Cox (*13*) with a 5 p.p.m. solution of the same substance on July 24th, 1940, nine weeks before the harvest date. The rate of drop from the control trees remained low, but fairly constant through the period. The effect of the spray, though small, was significant during the first three weeks, and thoroughly significant during the fourth ; its after-effect persisted until picking time. The total accumulated percentage drops were 21·5% from the controls, and 14·4% from the sprayed.

3. EFFECT OF LATE APPLICATIONS

Very late sprays, on the other hand, may sometimes be of use. Southwick and Shaw (1941b), for example, raise the question : " Suppose that a grower, for some reason or other, fails to spray or pick a block until one day he observes that perhaps one-third of the crop is on the ground ? Furthermore, he figures that he will not be able to pick the block for another week. Will hormone sprays be helpful ? This question cannot be answered categorically because no two situations are strictly comparable." These authors describe a test with McIntosh in Massachusetts where young trees (*78*), which had lost 20% of their crop, and old trees (*79*), that had lost 30%, were sprayed. " Under the conditions of these tests, a saving of about 50 bushels per acre could be attributed to the late hormone spraying." The old and the young trees behaved much alike. The value of a late application will depend on the size of the remaining crop as well as on the effectiveness of the spray ; a small crop will not pay for the spray even if the whole of it is saved.

Vyvyan (1941) sprayed the early apple variety Beauty of Bath (*5*) on the day when the fruit would normally have been picked and obtained a considerable reduction in drop during the next week and fortnight. The drop, however, even from the sprayed trees was very heavy and by the end of the fortnight the fruit tended to be rather over-ripe. Here, spraying at this late stage, could not be regarded as a means for postponing the time of picking, but might possibly be of some use for the reduction of the inevitable loss where postponement was necessary for other reasons. Roberts and Struckmeyer's (1943) successful use of late sprays in frosty weather (*90*) and (*91*) have already been mentioned. Several workers have found late sprays ineffective, even when applied before serious drop developed. Batjer and Marth (1941) sprayed York Imperial and Rome Beauty in the middle of October, " shortly before the normal harvest date for these varieties. Though little or no drop had occurred up to this time, the sprays had little effect in retarding a heavy drop which set in " about five days later, " and continued until the fruit was harvested." They suggest that " A possible explanation for failure in this case would be the very low physiological activity of the leaves and other tissues at this late date." Murphy (1941) likewise failed to control drop in Baldwin (*3*) with a spray applied late, and offers a similar explanation, but Hoffman *et al* (1942) suggest that " It is possible that the hormone sprays become less effective as picking maturity or . . . over-maturity is reached."

The evidence outlined above seems to suggest that very early sprays are of little value and very late sprays are often ineffective. Most of the best results with the hormone sprays have been obtained from applications at an intermediate period.

4. METHODS OF TIMING

The question arises, how is it possible to determine the best time to spray ? Several authors, e.g., Southwick and Shaw (1941b), Murneek (1940b) and Hoffman (1941b), have recommended that the sprays should be applied when the first few sound "commercial" fruits begin to fall, but, as Southwick and Shaw (1941b) point out, the time interval between dates of spraying and picking is important. They say this should not exceed 12 days in the case of McIntosh, though with certain other varieties the interval can be far longer ; in Winesap, for example, it may be four weeks.

Other authors, however, have found it unsafe to wait for the first signs of drop. Cole and McAlpin (1941), for example, speaking for conditions in Victoria, Australia, state that : " The spray cannot be timed with any degree of success by the method generally recommended, i.e., spraying as soon as signs of major drop appear. Most such ' drops' in Victoria are sudden of

onset and brief of duration, and the damage may be done during the two days which the spray requires to become effective. The more practical method is to fix the spraying date a certain number of days before the picking date, the exact number . . . depending on the duration of the effects of the spray on the variety concerned. This has been shown to vary from eight days to three weeks." Swarbrick (1945) makes the same recommendation for Beauty of Bath and Worcester in England, finding an interval of ten to twelve days about correct.

With most varieties, especially those liable to sudden " drops " shortly before the picking date, this latter method would seem the more satisfactory, though the trees should be watched, and the spray put on earlier, if signs of the start of a serious drop are seen. With some varieties, however, dropping may proceed over a long period, or a sudden heavy drop may occur many weeks before the best time for picking. Here the time to be covered tends to exceed the normal effective period of the spray. In cases such as these, it is probably better to spray rather earlier than with the other varieties, but local dropping tendencies and the relative likelihood of drop at different dates must be taken into account.

Another obvious method of covering a long period of danger is an early spray, followed, as its effect begins to wear off, by a second or even a third application. Many workers have examined the effect of repeated applications ; their results are described in the next section.

J. REPEATED APPLICATIONS

When examining the possibility of increasing the control of drop by making more than one application of the spray, it must be borne in mind that two sprays will be more expensive than one, even if applied at half the strength of the one, for the labour costs will be doubled. To be justified, therefore, the resulting increase in control must be considerable.

Many experiments have been carried out with repeated applications but the results are often hard to interpret, because so many factors may be involved. There are at least three ways in which a second application might increase control of " drop " ; in the first place it might prolong the period of control, if applied when the effectiveness of the first application was wearing off ; in the second place, where exact timing is important, two sprays on different dates will increase the chance of one spray being put on at the right date ; finally, repeated applications might increase the deposit of the growth substance.

Several workers have compared the drop from trees receiving two or more sprays with that from trees receiving none ; here it is impossible to be certain that one spray would not have given as good control as two—especially when only the final values of total drop are known Gardner *et al* (1940) got excellent control in Williams (*112*) with two applications, and the same authors, out of curiosity, gave some trees of the apple variety Gallia Beauty " seven sprayings at weekly intervals beginning October 12th, at which time normal drop had started and the fruits were ready to pick. On December 7th, eight weeks later, approximately 50% of the fruits were still hanging." Strickland *et al* (1941) used three applications on the apple varieties Jonathan (*49*) and Red Gravenstein (*92*) and the pear Williams Bon Chretien (*142*). They got good control and found that the fruit hung on until the flesh of the apples rotted and that of the pears liquified. Similar retention of the fruit, however, has been reported by Swarbrick (1945) in Beauty of Bath (*4*) as the result of a single application made ten to twelve days before the normal picking date, at the unusually high concentration of 15 p.p.m. Enzie and Schneider (1941) got good control in Stayman Winesap (*99*) with two applications, the first put on 35 days and the second 20 days before the normal picking date. Hoffman (1941a and b) applied two sprays, with a six-day interval, to some McIntosh trees (*64*) growing under conditions conducive to heavy drop. The fruits were picked, to avoid over-maturity, on the eleventh day after the first spray ; by then the control trees had lost 48% of their fruit, the sprayed only 4% and were showing no sign of a sharp increase in drop. The author points out that " with heavily dropping trees and under the conditions of this test the duplicate application . . . resulted in a longer period of drop control than did the single application reported by Gardner, Marth and Batjer." The same author controlled drop in some trees of the same variety (*66*) for twelve days by two applications at eight days interval ; during the last five days of this period the percentage of " fancy colour " increased from 60 to 80% of the fruit. Cool weather at the time of the second application may have contributed to this result.

Experiments where the effects of one and two applications of spray have been compared are summarized in Table 3. Most of them have been on McIntosh, where the relatively long period of natural drop and the comparatively short period of response to a single spray, make the possibility of prolonging the period of control by repeating the spray of particular interest.

The dates on which the two applications were made are shown in their respective columns. Single applications were always made on the 1st date, and in a few instances (*46*) and (*97*), they were made on the 2nd date also. In most cases the single spray was used at 10 p.p.m. and the duplicated sprays at either 10 p.p.m. or 5 p.p.m. Where other concentrations were used the values for the accumulated percentage drops are shown in *italics*, and the concentration used given under "Notes." In a few experiments, a single spray at 5 p.p.m. (*63*), (*72*) and (*76*), or 20 p.p.m. (*84*) was used in addition to that at 10 p.p.m. The values of the accumulated percentage drops for these additional treatments are given under "Notes." Thus in some experiments the two applications were each made at the same strength as the single application, and the trees received twice the amount of growth substance; in others the double applications were made at half strength so that all the treated trees received the same amount—some getting it all in one dose and others in two half doses.

Hoffman (1941a) in one experiment (*63*) obtained as excellent a control with one spray at 5 p.p.m. as with one at 10 p.p.m. or two at 5 p.p.m., but here the fruits were picked three or four days after the second application, so that this had little time to take effect. In other experiments the same author got better control with two applications at 10 p.p.m. (*65*), (*68*), (*70*) or 5 p.p.m. (*69*) than with one at 10 p.p.m. Greve, Kadow and Guy (1941) seem to have got rather poor control (*60*) with one at 10 p.p.m. or two at 5 p.p.m. but rather better control with two at 10 p.p.m. Overholser and his collaborators (1943) obtained less control (*75*) with two at 10 p.p.m. than with one of the same strength, but only a few trees were used. Southwick and Shaw (1941b) (*76*) found that two sprays at 10 p.p.m. gave much the same control as one at 10 p.p.m. or 5 p.p.m.; two at 5 p.p.m. gave slightly more control. The same authors, however, in other experiments got more control from two applications at 10 p.p.m. than from one at 10 p.p.m. (*77*) and (*84*) or one at 20 p.p.m. (*84*). Hilton and Spurr (1943) (*61*), on the other hand, got less control from two at 10 p.p.m. than from one at 20 p.p.m. Murphy (1942) (*72*) seems to have found two sprays at 5 p.p.m. more effective than one of the same strength, but usually less effective than one at 10 p.p.m.; date of application proved a more important factor.

The evidence is thus rather conflicting, probably because several factors may be involved. Time of application, for example, may be important. If the first spray was correctly timed and the second applied too late, two sprays may prove no better than one of the same strength and less effective than one of double strength. If, however, the first spray is put on too early, the second may have been timed correctly and thus give better control. An experiment by Ellenwood and Howlett (1942) on Stayman Winesap (*97*) seems a good example of this. Here some trees were sprayed on October 11th, some on October 16th, others on both dates; those sprayed on the first date showed no reduction in drop, those sprayed on both dates, or on the second date alone, showed considerable reduction. With Jonathan (*46*), however, the reduction in drop from two sprays was about the same as from a single spray applied either early or late. Of interest, also, in this connection, is Murphy's (1941) experiment (*71*) with McIntosh, where the first spray was applied on September 20th and the second on various dates. Here two sprays at 5 p.p.m., applied on the 20th and 26th, gave better control than two of 10 p.p.m. applied on the 20th and 28th. Two of $2\frac{1}{2}$ p.p.m., applied on the 20th and 26th, gave as good control as two of 5 p.p.m., applied on the 20th and 28th, or one of 10 p.p.m. applied on the 20th. Moreover, three sprays at a concentration as low as 1 p.p.m., applied on the 20th, 23rd and 26th, gave as good control as two of 10 p.p.m. applied on the 20th and 28th. Here it seems that September 26th was the date of greatest response, and time of application at least as important as number or strength of the sprays.

Another factor involved is the extra cover provided by two applications. Though the amount of growth substance is the same in two sprays of half strength as for one of full strength, the volume of spray fluid is usually double. A fruit stem must be wetted by the spray if it is to respond. Some of the stems missed by the first spray may be wetted by the second, while

Table 3.—Relative effect of spraying once and spraying twice.

Serial number as in Table 5	VARIETY. Dates of Sprays. 1st. Date	2nd. Date	*Accumulated percentage drops.* up to:—	Unsprayed	Sprayed. Once 1st Date 10 p.p.m.	Once 2nd Date 10 p.p.m.	Twice. Both dates. 10 p.p.m.	Twice. Both dates. 5 p.p.m.	Remarks.
	BRAMLEY								
8	Sept. 14	Oct. 2	Oct. 17	30	*16*		*14*		*at 6 p.p.m.*
	JONATHAN								
46	Sept. 27	Oct. 4	Oct. 21	19	9	8	8		
	McINTOSH								
54	Aug. 23	Aug. 23*	Sept. 4	39	15			8	*2 hr. interval.
		Aug. 26						3	
		Aug. 30						6	
60	Aug. 15	Aug. 22	Sept. 9	59	49		36	50	
	Sept. 18	Oct. 2	Oct. 13		*2*		4		Phyomone *20 p.p.m.*
61	Sept. 18	Oct. 2	Oct. 13	13	*4*		5		Parmone *20 p.p.m.*
63	Sept. 16	Sept. 21	Sept. 24-25	20	3*			3	*5 p.p.m. gave 3% drop.
68	Sept. 1	Sept. 5	Sept. 9	23	8		5		
69	Aug. 31	Sept. 5	Sept. 11	30	13			5	
70	Sept. 15	Sept. 18	Sept. 25	11	5		3		
		Sept. 28					13	18	N.B. 3 sprays (Sept. 20, 23,
		Sept. 26						10	26 at 1 p.p.m. gave 3%
71	Sept. 20		Oct. 4	31	17				drop.
		Sept. 26						*17*	*at 2.5 p.p.m.*
		Sept. 23						*22*	*at 2.5 p.p.m.*
	Sept. 9	Sept. 13	Sept. 21	25	4*			5	*5 p.p.m. gave 6% drop.
72	Sept. 11	Sept. 15	Sept. 23	29	7*			10	*5 p.p.m. gave 14% drop.
	Sept. 13	Sept. 17	Sept. 25	32	9*			7	*5 p.p.m. gave 9% drop.
75	Aug. 16	Aug. 28	Sept. 9	50	16		18		based on few trees.
76	Sept. 12	Sept. 17	Sept. 24	15	7*		7	6	*5 p.p.m. gave 7% drop.
77	?	+6 days	?	20	4		3		
84	Sept. 8	Sept. 12	Sept. 19	26	10*		5		*20 p.p.m. gave 7% drop.
	STAYMAN WINESAP								
97	Oct. 11	Oct. 16	Oct. 30	38	40	*22*	20		

Explanation.—The *Accumulated Percentage Drops* are the total drops during the period from the date of the application of the 1st spray until the date shown in the column headed " up to." They are expressed as *percentages* of the number of fruits present on the trees at the date of the 1st spray. Concentrations are as shown at head of column except when percentage drop values are in italics. They are then noted under " Remarks."

some of those missed by the second may have been wetted by the first ; the proportion of untreated stems is thus likely to be reduced when two applications are made. Batjer and Marth (1941), for example (*54*), got somewhat better control from two sprays at 5 p.p.m., applied with a two-hour interval, than from a single spray at 10 p.p.m., applied on the same day, and considered that this was due " no doubt to a more complete spray coverage." Two applications may also result in the building up of a greater deposit of active substance, especially when put on at the same strength as the single application.

The main object of " repeat " applications, however, is to prolong the period of control, and this does not seem to have been achieved very often. Hoffman *et al* (1943), in one experiment (*69*), had some success ; they found that one application at 10 p.p.m. began to " run out " about the seventh day, but a second of the same strength, applied five days after the first, controlled drop quite satisfactorily until the twelfth day, when the fruit were picked. Batjer and Marth (1941), however, found (*54*) a single spray at 10 p.p.m. began to " run out " between the tenth and twelfth days, while repeat sprays at half strength, applied two hours, three days, or seven days later, all " seemed to be effective for only two days longer. By the fourteenth day all trees were in a high state of drop irrespective of treatment." Most investigators seem to have had similar experience and consider that a second spray is of little value provided the first spray has been timed correctly.

In practice, correct timing is sometimes difficult, especially with varieties, such as McIntosh, with a short responsive period. Batjer (1943) suggests that " one alternative would be to spray somewhat ahead of the drop." If it were found that this spray had been put on too soon and it was thought advisable to postpone picking beyond the protected period, a second spray could be applied six or seven days after the first. If the first had been put on " somewhat near the harvest period . . . picking may be well under way by the time the second . . . should be made " and only part of the block need be sprayed.

K. METHODS OF APPLICATION AND QUANTITIES PER TREE

1. SPRAYS

The growth substance has usually been applied in the form of a spray, and, except where otherwise stated, this method was used in all the experiments summarized in Table 5. As the pure chemicals naphthaleneacetic acid and naphthalene acetamide are only slightly soluble in water, it has been customary to dissolve them in a little alcohol before mixing them with the spray solution. Where commercial preparations are used, this is not necessary.

(*a*) Methods for securing good cover

Wetting the fruit stem seems to be the essential condition for success ; wetting the calyx end of the fruit has less effect and wetting the leaves practically none. This fact governs the technique to be adopted and the quantities of spray required. Cole and McAlpin (1941) consider that " better results will be obtained by spraying more downwards than upwards as contrasted with the codling moth method of spraying more upward into the calyx." Batjer (1941) states that " a tree should be sprayed both from the inside and the outside," as it is difficult, if not impossible, to cover a heavily-loaded tree adequately " from the outside only." He also recommends that " every effort should be made to do a thorough job in the top of the tree since the best fruit is usually borne in this portion . . . Also, when an apple falls from the top it is likely to knock off several fruits on its way down." Greve, Kadow and Guy (1941), in some experiments on McIntosh, Delicious and Stayman Winesap, applied the spray " lightly to only the outside portion of the tree. When sprayed in this manner, McIntosh dropped as badly as the unsprayed trees, Delicious dropped 2% more, and Stayman Winesap . . . 5% more than the trees sprayed thoroughly with materials at half strength." They consider, therefore, that where economy in material is necessary, " it would probably be better to use the materials at half strength and spray the tree thoroughly than to use the materials at full strength and not spray thoroughly." It is also better to apply too much than too little ; Batjer and Marth (1941) compared a light application of about 5 gallons per tree with a normal one of about 10 gallons, on some Delicious (*15*) trees carrying about 7 bushels of fruit ; the light application was " just

half as effective " as the normal one. According to Batjer (1941) the quantity required probably depends in part on the fruiting habit of the tree ; short-stemmed varieties, and those prone to carry their fruit in clusters, are likely to require larger quantities than varieties such as Williams Early Red, Rome Beauty, Delicious and Golden Delicious.

(*b*) **Methods for gauging quantities per tree**

Various methods for gauging the quantities required per tree have been suggested ; these may be summarized as follows :—

(i) AGE OF TREE. Burkholder and McCown (1941) applied commercial " harvest sprays " at the rate of 0·40 to 0·50 gallons for each year of the tree's age ; they considered this rather a light application. This method would not be suitable under English conditions, where trees of the same age may differ widely in size and crop according to the variety of rootstock upon which they have been worked.

(ii) AMOUNT USED IN OTHER SPRAYINGS. Cole and McAlpin (1941) state that " The amount of spray required is greater with the ' drop ' spray than with the codling spray . . . For example, a tree requiring $2\frac{1}{2}$ gallons for a codling moth spray will take 3 gallons of the ' drop ' spray."

(iii) ESTIMATED CROP. Most workers have based the quantities applied per tree on the estimated number of bushels of fruit borne upon it. The usual recommendation they make is " $1\frac{1}{4}$ to $1\frac{1}{2}$ gallons of spray for every bushel of fruit."* This is probably the best method to adopt.

2. DUSTS

A certain amount of work has been done with dusts containing growth substances. Experiments where these have been compared with sprays are summarized in Table 4. Where two or three different commercial preparations were used in a single experiment, the respective values for the accumulated drops are bracketed together.

Hoffman *et al* (1942) point out that " Trees can be dusted much faster than they can be sprayed. For this reason a dust may, in some cases, have a decided advantage over a liquid spray." Moreover, when the trees are rather crowded and in full crop, it is sometimes difficult to manœuvre spray tackle through an orchard without knocking off some of the fruit ; under these conditions some growers say they prefer to use a dust.

Dusting has certain disadvantages, however, which must be balanced against these advantages. It is apparently more difficult to gauge the amount deposited on a tree and this is therefore rather liable to vary. The range of weather conditions suitable for dusting is probably rather narrower than for spraying ; the best results seem to have been got (Hoffman *et al*, 1942) with applications where light or heavy dews occurred each night. Dusting, it seems, is best done in the early morning, while the leaves are still wet with dew, rather than in the warmer part of the day which is the best time for spraying.

The relative efficiency of dusting and spraying seems to vary with the locality and the variety. Hoffman *et al* (1942 and 1943), working in the Hudson Valley, New York State, on Williams Early Red (*116*), Baldwin (*2*) and McIntosh (*68*), (*69*) and (*70*), concluded that : " There is nothing to indicate that either of these methods . . . resulted in a more effective control of drop than the others." Southwick (1942), however, tried dusts and sprays on McIntosh in Massachusetts and found " Dusting was not as effective as spraying where, with each method, equivalent amounts of the active ingredients were applied. In further experiments (Southwick, 1943), he found " With Duchess (*33*) and Wealthy (*108*) dusting was not so effective as spraying ; while with McIntosh (*84*) and (*85*), though the results were variable, dust applications gave encouraging results. In another experiment (*86*), on the same variety, carried out in 1943, Southwick (1944) compared one and two applications of dust at " regular " and " double " strengths with one and two applications of spray at ·001% and one at ·002%. The " regular " strength of dust was made up so that 1 lb. dust was equivalent to 10 gallons of ·001% spray. He reports that " The data show fairly uniform success from all treatments,"

* This represents 1 to $1\frac{1}{4}$ imperial gallons.

Table 4.—Relative effects of sprays and dusts.

Serial number as in Table 5	VARIETY.		*Accumulated percentage drops.*					REMARKS.
			CONTROL.	ONE Application		Two Applications		
				SPRAY.	DUST.	SPRAY.	DUST.	
2	BALDWIN	N.Y.	56	19	18			
33	DUCHESS	Mass.	55	{9 7}	{36 29}			
68	McINTOSH	N.Y.	23	8	6	5		
69	,,	N.Y.	30	13	{13 13}	*5*	4	*at 5 p.p.m.*
70	,,	N.Y.	8	3	{3 5}	2	{4 2}	
81	,,	Mass.	*210*	*130* *73*	*140*			Drops after application as % drops before application
82	,,	Mass.	*141*	*112*	*146*			ditto.
84	,,	Mass.	37	{23 31}*	{44 32}	8	{20 26 30}	*20 p.p.m. gave 16% drop.
85	,,	Mass.	25	8	11			
86	,,	Mass.	18	9 *4*	8 *8*	7	11 *8*	*20 p.p.m.*
108	WEALTHY	Mass.	52	{52 47}	59			
109	,,	Mass.	64		68 *51*		*53*	No sprays. *20 p.p.m.*
116	WILLIAMS E. RED	N.Y.	82	2	2			

All concentrations were 10 parts per million and all accumulated drops expressed as percentages of initial crop, except the values in *italics*, which were as shown under " Remarks. ' Bracketed values are shown for different preparations of the same chemical.

but considers that they " seem to show a trend toward better drop control with the double strength dusts and spray and with two applications." He does not regard the results as conclusive and considers that more work is required. He reports that weather conditions were rather peculiar and, in some instances, resulted in an early period of drop being followed by one of light drop.

Vyvyan (1946) got no control of drop in Bramley (*11*) in 1945, but a spray proved almost as ineffective (*10*).

No other work seems to have been done as yet with dusts, and these should be tested on other varieties and under other climatic conditions before they can be recommended for general commercial use.

3. INJECTION

Gardner *et al* (1940) injected large trees of McIntosh with 5 litres of ·01% N.A.A. and N.A. by " boring holes in the trunk and allowing the trees to draw in water solutions of the chemicals." In other cases, holes in the trunk were filled with a 5% mixture of the growth substance in lanolin paste. In neither case was any effect on fruit drop detected. No other worker seems to have reported work on these lines.

4. APPLICATION TO SOIL

The same authors poured 20 gallons of ·001%, ·0005% and ·00025% growth substance round the base of individual 8-year-old trees of the apple variety Thurley, as fruit drop set in. " Some slight influence of this treatment over the check was noted, increasing with increased concentration, but the efficiency of the method was poor compared with the spraying method." Even this slight effect seems of interest from the point of view of the problem of translocation, in view of the apparent absence of translocation from the leaves. No other worker seems to have explored this method further.

5. VAPO-DUST AND AEROSOL

Hesse and Davey (1943) have examined the possibility of using the vapo-dust method in an experiment with naphthaleneacetic acid and Fruitone on Elberta peaches (*146*). The sprayed trees showed only a slight advantage at the end of three weeks, but no other methods of application were included in the experiment for comparison.

Goodhue (1942 and 1944) and Zimmerman and Hitchcock (1944) have recently been examining the aerosol method of treating plants. Their results seem promising but the method must be regarded as still in the experimental stage.

L. SUPPLEMENTARY SUBSTANCES

1. SPREADERS

Gardner and his collaborators (1940) considered that " The common practice of adding a spreader or sticking agent . . . is desirable . . . The choice of spreader or sticker is apparently immaterial." They found that " Bentonite. . . . had no influence . . . on the activity of naphthaleneacetic acid " (*100*). van Stuivenberg (1941) obtained no benefit from adding casein to his sprays. Overholser and his collaborators (1943) reported a slight increase in control of drop in Winesap (*123*) where Vatsol was added. Several workers have used spreaders as a routine measure. For example, Hitchcock and Zimmerman (1941) used casein or Penetrol, Greve and Kadow (1941) used Vatsol and Hesse and Davey (1943) used Vatsol in one experiment and blood albumen in another ; here, of course, the effect of the spreader is not known. Very recently Batjer and Marth (1945) have reported a very striking increase in the effectiveness of naphthaleneacetic acid (*119*) as a result of the addition of Carbowax (polyethylene glycol) to the spray.

The possible effect of spreaders upon the keeping quality of the fruit must not, however, be overlooked. Reyneke and Pearse (1945) report that " the application of wetting agents, or wetting agents together with hydrochloric acid for the removal of arsenical residues, increased

the rate of respiration, and reduced the storage life of Bon Chretien pears considerably." In this case the wetter (Areskap) was applied after picking and before storage ; it partially removed " the natural waxy covering " from the fruit.

These results suggest that further work on spreaders is required before general recommendations for their use can be made.

2. CITRIC ACID

Gardner *et al* (1940) tried the effect of adding citric acid at the rate of 190 gm. per 100 gallons. They did this largely on theoretical grounds. They thought citric acid might increase the effectiveness of the spray by raising the hydrogen-ion concentration and thereby decreasing the dissociation of the naphthaleneacetic acid, which probably enters the cells as non-dissociated molecules. In this case it should be more effective with the acid than with the amide (which does not dissociate). " With the early ripening varieties Early McIntosh and U.S.D.A.51, sprays with citric acid added gave better control than sprays without . . . in the case of " the acid, " but no additional benefit in the case of " the amide, which is in accordance with the theory, but later results failed to confirm it. Citric acid, together with oil, however, gave " a definite effect " with Rome Beauty (*95*). " Possibly the addition of acid, by depressing the dissociation, influenced the partition of the naphthaleneacetic between the water and oil phases of the emulsion, increasing the concentration in the oil phase. It is reasonable to expect that . . . relatively more oil than water sticks to the plant." Strickland *et al* (1941) added sufficient citric acid to their spray solutions to make them acid to litmus paper. The marked control they got with their sprays seems to show that the addition of the citric acid was harmless, if not beneficial.

3. SUMMER OIL

Gardner *et al* (1940) tried the addition of oil to the sprays because they thought it might " increase the effectiveness of the compound, through aiding its penetration or maintaining a film of the substance in oil." They found addition of oil " appreciably increased the effectiveness . . . and to some extent the duration of the effect " in Red Duchess (*31*) and Rome Beauty (*95*). This result was obtained, however, with the acetamide as well as with the acid, in spite of its lower solubility. They consider that this suggests that " the effect of the oil was to ' pile up ' the amount retained on the fruit, just as when oil is used in codling moth sprays to build up a residue of insecticide." Southwick and Shaw (1941a) reported that the addition of a small amount of summer oil increased effectiveness of the sprays. Hoffman (1941b) tried naphthaleneacetic acid at ·0005% without oil and at ·001% with three types of oil on McIntosh (*67*) ; sprays with oil gave more control, but this may have been due to the higher concentration of growth substance. Addition of ·25% oil to N.A.A. spray on Wealthy (*106*) seems to have had no appreciable influence on the effectiveness of the hormone, and the same held good for an experiment on McIntosh (*63*). Overholser *et al* (1943) report that oil did not diminish the effect and gave slight indications of increase with Winesap. Bryden (1941), working on Williams Pear (*138*) in New South Wales, got less control of drop with a spray containing oil than from one with none, and, according to Whittaker and MacKenzie (1944), considers that at Bathurst the " indications are that oil does not increase the effectiveness to any great extent."

The possibility of harmful effects of oil on fruit quality, when sprayed on to the trees shortly before picking time, must not be overlooked. Gardner (1940) has pointed out that the very small amounts used—$\frac{1}{8}$% to 1%—" can scarcely be detected on the fruit after spraying and . . . results in no observable modification of the red colour as frequently occurs with higher oil concentrations." But Haller (1943) reports that " Limited results indicated that softer fruit more subject to decay may result from the addition of 0·25% to 0·50% of summer oil to the pre-harvest sprays."

More recently, however, Reyneke and Pearse (1945), working in South Africa with Bon Chretien pears and Golden Delicious apples, have found that " oil applied evenly in a thin film over the surface of the fruit during the pre-climacteric phase reduced the rate of respiration and increased the juice content. Applied after the pre-climacteric phase it maintained a low

respiration and a high level of juice." The effectiveness of various oils . . . varied in the order : Arachis, olive, butter, mineral, soya, maize . . . The unsaturated, non-drying oils were more effective than the more saturated, medium and drying oils." In most of their experiments the oils were applied after the fruits were picked but they also report that "pears from trees which received oil sprays showed a reduced respiratory activity and broke down and scalded less rapidly than those from trees which were sprayed with lead-arsenate or those from unsprayed trees." These authors did not examine the effect of sprays containing oil and naphthaleneacetic acid, but they found that " indoleacetic acid, added to oil in low concentrations, appeared slightly to increase the rate of respiration, while a high concentration of hormone and oil significantly reduced it."

The evidence on the effect of oil upon the efficiency of growth substance sprays and on the subsequent storage life of the sprayed fruit is thus rather conflicting. The type of oil used and the physiological condition of the fruit at the time of spraying seem important factors ; it is possible that varietal differences in response may also be found.

4. COLOURING AGENTS

Certain chemicals are sometimes used as sprays with a view to increasing the colour of the fruit. Batjer and Marth (1941) have described an experiment, with the apple variety Williams Early Red (*110*), designed to show how far these chemicals are compatible with anti-drop sprays. The colouring agents they used were a-naphthalene acetonitrite,* methyl thiocyanate and methyl isothiocyanate, and sodium thiocyanate. Used alone, these chemicals apparently had no effect on fruit drop, except the last which seems to have increased it somewhat. Added to a growth substance spray, none of them reduced its efficiency, but none of them seems to have resulted in an increase in fruit colour.

M. COMPATIBILITY WITH INSECTICIDES AND FUNGICIDES

It would obviously be an economy if the growth substance for the control of pre-harvest drop could be added to some routine insecticide or fungicide, instead of being applied as a separate spray. Usually, however, they have to be applied much later in the season than these routine sprays, and as Gardner (1940) points out, " There are probably few instances in which they could advantageously be added to late cover sprays." Kadow and Hopperstead (1942) remark, however, that " In some parts of the country early to mid-season varieties require fungicides and insecticides at such times as to make their application with fruit drop sprays desirable. Under Delaware conditions, second brood codling moth, Japanese beetle, and minor fungus diseases present such a problem." The same problem might arise in England with late oil or lime sulphur sprays applied to control red spider.

There is also a possibility, well worth investigating, that growth substances added to a routine spray, such as lime sulphur, bordeaux mixture or summer oil, applied at the normal time, might reduce the fruit and leaf drop that occasionally results from these sprays.

In view of these considerations, it seems important to know whether the growth substances are compatible with the chemicals used in the routine insecticide and fungicide sprays. The influence of residues, left on the trees by these sprays, upon the effectiveness of subsequent growth substance sprays, is also important. Considerable work on this problem has been reported.

Hatcher, working at East Malling (Vyvyan, 1941 and 1946), has found that neither lime sulphur, bordeaux mixture, nor lead arsenate reduce the activity of a solution of alpha naphthaleneacetic acid, when this is measured by the " coleoptile test," and several workers have carried out experiments in the field ; the results of these are summarized below.

1. SUMMER OIL

Summer oil sprays, to control red spider, cannot be used with safety in some localities, including East Malling, as they sometimes cause severe fruit drop. Vyvyan (1941) examined the possibility of controlling the oil-induced drop by adding growth substance to the oil spray.

* According to Batjer = a-naphthalene, methyl thiocyanate and isothiocyanate.

Trees of Cox (*13*) were sprayed, towards the end of July, with : (*a*) tap water, as a control ; (*b*) a 1% oil spray ; (*c*) the same with the addition of growth substance ; (*d*) the same followed, a fortnight later, by a growth substance spray. The last treatment was included because oil-induced drop sometimes does not occur until a month after spraying, and growth substance might not remain active so long. The sprays containing growth substance considerably reduced drop, but unfortunately, from the experimental view point, the oil that season failed to promote dropping. A repeat of the experiment with the omission of treatment (*d*), on the same variety in 1943 (*14*), gave much the same values for percentage drop as in 1940, but owing to tree variability, none of the differences were statistically significant. Further work on these lines seems called for.

2. LEAD ARSENATE

Greve and Kadow (1941) found no reduction in control of fruit drop when lead arsenate was added to an anti-drop spray applied to McIntosh, and Overholser *et al* (1943) report the same result when lead arsenate, and $\frac{1}{4}$ pint oil per 100 gallons, were added to a spray on Delicious (*26*). Vyvyan (1946) got inconclusive results with Bramley (*9*).

3. SAFENERS AND SPRAYS CONTAINING LIME

The evidence on the effect of adding lime to growth substance sprays is rather conflicting. Gardner *et al* (1940), working with McIntosh, found that these substances did not diminish the effectiveness of the growth substance. Ruth and Powell (1944) obtained the same result with Delicious (*29*). These authors also found that bordeaux mixture caused no reduction in control. Kadow and Hopperstead (1942), however, found that when lead arsenate (2 lb.) and bordeaux mixture (1 lb. copper sulphate and 3 lb. lime) were added per 100 gallons of a growth substance spray, and used on either Williams (*117*) or Delicious (*22*), control of drop was greatly reduced. In the same experiments the addition of 3 lb. aluminium sulphate and 20 lb. lime per 100 gallons caused a similar reduction. They concluded that " While sprays containing lime do not completely destroy the value of fruit drop chemicals they reduce their effectiveness markedly." Overholser *et al* (1943) tried zinc sulphate at $\frac{1}{4}$ lb. and lime at $\frac{1}{2}$ lb. per 100 gallons on Winesap (*124*). They found that lime, when used alone, somewhat reduced the control of drop, but zinc sulphate, used either alone or with lime, apparently made the alpha naphthaleneacetic acid spray more effective.

4. MILD INSECTICIDES AND FUNGICIDES

Kadow and Hopperstead (1942) (*22*) and (*117*) found a-naphthaleneacetic acid compatible " with Black Leaf 155, Genecide, Phenothiazine and Derris (4% or 5% rotenone). Observation in commercial orchards using the sodium salt of a-naphthaleneacetic or a-naphthaleneacetic acid and amide in combination with Black Leaf 155 indicates these combinations are compatible also." Greve and Kadow (1941), however, got some indications in the previous season that the effectiveness of Fruitone on McIntosh was reduced by Genecide.

The converse problem of the effect of growth substance on the insecticidal properties of insecticides has not yet received much attention ; Kadow and Hopperstead (1942) report that their " records " were " inconclusive, but tended to indicate that they were not harmed."

5. SPRAY RESIDUES

The effect of spray residues on the activity of subsequent anti-drop sprays is important and has received some attention. Gardner *et al* (1940) reported that the residues of lime sulphur and bordeaux mixture had no apparent influence on the effectiveness of these sprays. Overholser *et al* (1941), however, got little control of drop when they sprayed Delicious trees which were showing considerable spray injury from a " severe codling moth spray " programme, but got good control of drop in another group of trees of this variety which had received a " moderate " programme. The number of trees involved, however, was very small. Kadow and Hopperstead (1942) report that " Fruit drop sprays applied over weathered deposits of lead arsenate, copper sulphate and lime were not affected by the deposit. It is supposed that

an interval of three or four days to allow for the carbonation of the excess lime would be necessary to render previously applied lime sprays harmless to later applications of fruit drop chemicals."

N. EFFECT ON QUALITY OF FRUIT

The commercial value of a crop carried by a tree depends not only on the number of fruits but also on their quality ; possible effects of sprays on quality are therefore important.

The various characteristics, that collectively make up " quality," include size, colour, taste, resistance to damage in transit, and storage capacity ; their relative important varies with the variety and the market requirements. For example, some varieties of fruit sell best when of medium size, others when relatively larger ; good colour is a greater asset in some varieties, such as McIntosh and Worcester, than in some others ; resistance to damage in transit is of special value in fruit required for distant markets while storage capacity is of little importance in varieties that command their highest price when put on the market as soon as they are picked.

The effect of growth substance sprays on these various characteristics may be either direct or indirect, but in practice it is not always easy to determine whether it is the one or the other. If no drops had occurred from either sprayed or unsprayed trees, and both had been harvested on the same day, any differences in the quality of the respective fruits could be attributed to a direct effect of spraying. Where sprayed and unsprayed have dropped at unequal rates, differences in quality may arise indirectly in one of two ways.

1. INDIRECT EFFECTS

In the first place, there may have been selective dropping. This has been pointed out by Overholser *et al* (1942) as follows : " Perhaps some confusion has arisen regarding the effect of the pre-harvest sprays on maturity . . . due to the fact that over-ripe fruit may drop from unsprayed trees before the fruit is harvested, but be retained on sprayed trees . . . This would give the appearance, especially to the pickers, that the spray had actually hastened the maturity of the fruits." This factor would still operate, of course, even if the dropped fruits were not over-ripe, provided they were less unripe than those left on the trees. Moreover, those retained on the sprayed trees will ripen faster than their opposite numbers dropped from the unsprayed. An apparent effect of spray on fruit size may arise in the same way, if dropped fruit tend to be larger than the fruit retained (van Stuivenberg, 1942).

In the second place, a spray might indirectly influence quality through its effect on the size of the crop. The few fruits left on the unsprayed trees will be under different nutritional conditions than the larger number retained on the sprayed. Southwick (1940) points out, " After any drop there may be an exaggerated increase in the growth of the fruits remaining as a result of increased supplies of nutrients and especially of water."

In the case of a heavy drop shortly before picking time, however, the few fruits remaining on a tree are usually poorly developed and undersized.

2. DIRECT EFFECTS *

The evidence is somewhat conflicting, but, in general, suggests that there is little direct effect of a spray on fruit quality, except, perhaps, occasionally on colour unless the spray is used at an unusually high concentration. Overholser *et al* (1942) report that " Experiments conducted at the Washington Agricultural Experimental Station . . . indicate that the maturity of the fruit of d'Anjou and Bosc pears and Winesap and Delicious apples was not hastened or retarded either before harvest or in cold storage by the application of the pre-harvest sprays." They qualify their statement by pointing out that the experiments were with the pure a-naphthaleneacetic acid applied after standard codling moth sprays. Commercial anti-drop sprays were not tried and they suggest that different results might possibly be found if " certain less

* Dr. C. West has kindly carried out a test of the relative keeping quality of Bramley Seedling fruit from control and sprayed trees (*11*) at the Ditton Laboratory. He reported in correspondence on 15/3/46 as follows : " The only significant difference between them is that the controls were very slightly more yellow than the treated fruits. The amount of wastage was practically identical in each case."

widely used codling moth sprays were used, either before or with, the pre-harvest sprays." They also point out that other varieties might respond differently to those used. Haller (1943) carried out storage tests on apples of the varieties Delicious, Rome Beauty, Stayman Winesap and York Imperial in 1939 and Jonathan, Starking, Stayman Winesap and York Imperial in 1940. He summarizes his results as follows : " Storage tests with six varieties of apple given pre-harvest sprays of a-naphthaleneacetic acid to delay dropping did not show any direct effect of the sprays on the firmness of the apples or the development of decay, breakdown, or scald during storage when compared with unsprayed apples picked at the same time." Perhaps Christopher and Pieniazek (1943) have provided the most conclusive evidence on the lack of direct effect in the case of the variety McIntosh, sprayed with commercial pre-harvest sprays. They retained the fruit on some trees by the use of the sprays, and on other trees by artificially strengthening their attachment by means of adhesive tape. The effect on quality due to longer retention on the tree, was found to be the same whichever method was used. This method eliminated the possibility of indirect effect due either to selective dropping or change in relative weights of crop. One possible theoretical disqualification, of course, remains and might have to be examined if differences between sprayed and unsprayed were found. An abscission layer may be formed in the stems of the unsprayed fruit, even if the adhesive tapes prevent the weight of the fruit from disrupting the tissues at the weakened point. The presence of such an abscission layer might influence the translocation of materials to or from the fruit and thus establish a difference between fruit retained by spray and those retained by tapes.

van Stuivenberg (1941) found no " marked noticeable quickening " in ripening of fruit of Sterappel or Belle de Boskoop varieties which had been sprayed with naphthaleneacetic acid at 10 p.p.m. shortly before picking. In the case of the Sterappel fruit, however, a significant difference in the percentage of total sugar did develop in cold store. A large storage experiment, with fruit of this variety from more than one source, revealed no differences in percentages of sound fruit up to some time in February, between those from unsprayed trees and trees sprayed at concentrations of from 5 to 10 parts per million. Nor were there differences in amount of rot and lenticel spot. This author came to the conclusion, therefore, that there need be no fear of a growth substance spray, such as is used in ordinary practice, having a " pernicious influence " on the keeping quality of this variety.

van Stuivenberg (1942) found, however, that high concentrations did quicken ripening. Fruits of Sterappel, picked at two different dates were treated with concentrations of 10, 50, 100, 150 and 200 parts per million. By March 17th, those treated with 10 p.p.m. did not appear riper than the untreated, those that had received 50 and 100 p.p.m. seemed somewhat riper, those that had been treated with the two highest concentrations were obviously riper than the untreated fruit. In fact these treated fruits from the earlier picking produced some flavour, while the untreated produced none. He suggests that these substances might be used to ripen pears of varieties that normally ripen with difficulty.

The same author found that a spray of 50 p.p.m. applied in June in an attempt to control " June Drop " in Yellow Transparent, caused a quickening in ripening. The fruit, though under-sized, hung ripe on the trees. Some specimens burst.

There is some evidence that the sprays may sometimes have a direct effect on fruit colour and maturity. Southwick (1943) reported that he got much more colour in Wealthy fruit (*108*) sprayed with high (·004% and ·002%) than with lower concentrations. Gardner (1940) remarked that the increase in colour in the sprayed fruit was so outstanding that it made him wonder if there might be " some more direct colour effect than can be explained by the fact that the fruit hangs longer on the tree." A somewhat similar instance occurred at East Malling in 1941 ; fruit from sprayed trees of the apple Miller's Seedling (*87*) did not appear noticeably different from that from unsprayed trees at the time of picking, but developed a much brighter colour in about a week. Here the effect may have been due in part to selective dropping.

Overholser *et al* (1944) remarks that " If, following spraying with growth chemicals, Bartlett pears are left on the trees longer than ten days, the sprayed pears appear to ripen more rapidly than do unsprayed pears." Here the effect would appear to be a direct one.

Bryden (1941), on the other hand, in New South Wales, reports (*138*) that fruits of the Williams pear, which had been given a hormone spray, were a deeper green and were apparently

less mature than those from unsprayed trees. If this should prove general for other pears in all localities it would be very important, for the danger of over-maturity through postponed picking is probably greater in pears than in most apples, because pears must usually be marketed and stored in a less mature condition than that permissible for apples.

3. EFFECT OF POSTPONEMENT OF PICKING

The main effect of the sprays is the indirect one resulting from the postponement of picking made possible by their application. This is more important in some varieties and certain localities than in others. Gardner *et al* (1940), for example, states for New York conditions that a delay of eight or nine days "means much in the way of increased colour in McIntosh, yet a further delay would be highly desirable." Hilton and Spurr (1943) state that much of the fruit of the same variety in Nova Scotia "would have yielded better size (and therefore more barrels) and better colour (and therefore better grades) if it had remained another two weeks on the tree." Batjer (1942) says there are few orchards of the apple variety Williams where a grower is able by ordinary orchard practices to keep the apples on the tree until they develop adequate colour without serious loss by dropping. Hoffman (1941b), speaking of the same variety, states that they "usually drop heavily about the time when they begin to develop No. 1 colour." Greve and Kadow (1941) state that 'If Grimes Golden could be held on the tree a little longer than usual and picked when they show considerable colour instead of picking while still grass green, the quality of the fruit and the demand for it would be much better."

(*a*) On size and colour of fruit

As Hoffman (1941b) points out, "Apples continue to increase in size as long as they are attached to the spur." This is particularly true of early varieties, especially those that tend to be harvested in a relatively immature condition to avoid danger of loss by drop. Archbold (1932), for example, found that Worcester was still relatively immature and still growing rapidly at the commercial gathering date, while Bramley, at the corresponding date, was comparatively mature and showed little subsequent growth. Southwick (1940) found that McIntosh apples increased 40% in volume during the period between the first week in September and the first week in October. Hilton and Spurr (1943) picked sprayed and unsprayed McIntosh (*61*) on three dates, September 18th, September 30th and October 13th and found a 24% increase in weight per fruit during the first period and an 11% increase during the second. Hilton (1944) got rather similar results the next season (*62*). As these authors point out, this greater weight per fruit means not only more bushels per tree, but also larger proportions of the crop in the upper size grades and therefore higher price per bushel. The same authors also investigated the colour increase resulting from postponed picking. They found that, whereas the greatest size increase occurred in the earlier period, September 18th to 30th, the greatest increase in colour was in the second period, September 30th to October 13th. In 1943, however, the colour increase seems to have been less. The net gain in price, in Canadian money, per barrel of fruit in 1942 was from 3·66 dollars on September 18th to 4·56 dollars on October 13th. The gain per tree, taking into account the larger number of bushels, was from 14·64 to 24·32 dollars.

Batjer (1942a) reports that in 1940 2,000 acres of Delicious were successfully sprayed in the Wenatchee district, and that "packing-shed records showed that the sprayed fruit advanced a full grade over unsprayed, due to increased colour. It is estimated that this colour increase alone paid for the spray material."

Petch (1940) reports that, as a result of postponed picking made possible by spraying, the colour of the apple varieties Wealthy and Atlas was in some cases greatly improved from a striped to an almost solid red. Swarbrick (1945) reports that a delay, made possible by spraying, of five days in Beauty of Bath (*4*) and of fourteen days in Worcester (*125*), resulted in fruit of the very best quality. "Every apple not mechanically damaged was of 'tray' quality and in normal times would have commanded the highest price.' The Worcesters had a clean fresh flavour, more aromatic than is usual with this sort. They were crisp in texture and juicy and without that tendency to woolliness so frequent in Worcester Pearmain."

(*b*) **On eating quality and storage capacity**

Fruits continue to ripen as long as they are left on the tree, the value of postponement of picking depends, therefore, on the stage of maturity required and on whether this is attained by the time of the normal picking date. A fruit that normally has to be picked, to avoid loss by dropping, before it is in the optimum condition for its particular purpose, is likely to benefit from a postponement of picking, provided this period is not unduly prolonged. The proper stage of maturity depends upon the purpose for which the fruit is required and on the kind of fruit. Fruit for storage needs to be picked less mature than that for the immediate market or for canning, especially in the case of pears ; but even here postponement seems sometimes to be an advantage. For example, in the case of McIntosh, Christopher and Pieniazek (1943) found that a delay of eight days not only increased fruit size and colour but improved eating quality and had no effect on storage capacity. Hilton and Spurr (1943) (*61*) found that the fruit from their third and last picking " stood up in storage as well or better than the earlier pickings " and Hilton (1944) confirmed this the following season. In each case storage seems to have been " common cellar storage " and up to the beginning of December. Southwick (1940) reports that " results at Amherst show that late picking of McIntosh usually results in increased storage life of the fruit. This is in line with recent findings in New Hampshire." Swarbrick (1945) reports that a small sample of Worcester (*125*), picked fourteen days late, and kept in ordinary store, were in good eating condition at the end of October. Certain varieties present a rather special problem ; here the individual fruits ripen rather rapidly, so that each is in the proper condition for picking for a few days only, but the various fruit on the same tree ripen unevenly and are ready for picking on different dates. In varieties of this type, it is usually necessary to pick the tree over on two or even three occasions. As the anti-drop sprays merely keep the fruit from falling and do not prevent them from getting over-ripe, they do not necessarily do away with the necessity for successive pickings. Where, in addition to ripening unevenly, the fruits tend to fall before they are ready to pick, the sprays will be useful even though they do not permit a single picking. Where the fruits normally hang well until ready to pick, the main use of the spray, if any, would be to make picking more easy by reducing the danger of immature fruit being knocked off during the process of the earlier pickings. Williams Early Red seems to be a variety of this type, according to Greve and Kadow (1941), Batjer (1942) and Hoffman (1941b) ; Hoffman however, considers that " With one application of the . . . spray, thoroughly applied just as the first few fruits drop, it seems possible that the entire crop can be harvested in a single picking . . . after the development of fancy colour." He emphasises, however, that " The danger of over-maturity must receive consideration when the spray is used on Williams Early Red and other varieties ripened during warm weather. Early McIntosh, according to this author, is another variety whose fruits " mature over a long period . . . The trees must be picked over at least twice, and in many cases three times, if all the crop is to be harvested at the best stage of maturity and colour . . . Even with this there is usually a large loss from drop." He found sprays made the picking more convenient.

4. DANGER OF OVER-MATURITY

Most authorities emphasise the necessity for picking the fruit at the proper time for its particular purpose and the danger of over-maturity. An anti-drop spray is an excellent tool when properly used, but, like many tools, can be dangerous if wrongly used. This warning is all the more necessary, because one of the commonest criteria for determining the correct time for picking is the ease with which the fruit can be removed from the tree. For example, Kidd and West (1937), speaking of the stage at which Bramley Seedling should be picked, suggest that " A practical index of this stage that is fairly reliable is when the fruit can just be detached by gently twisting it on its stalk." This index may not hold good when the stalk has been reinforced by use of a growth substance spray.

Batjer and Marth (1941), speaking of Williams Early Red, state that " if these fruits are not harvested within a day or two after they would have normally dropped . . . over-ripeness develops, particularly under high temperature conditions."

P. OTHER EFFECTS OF GROWTH SUBSTANCE SPRAYS

1. EFFECT ON CODLING MOTH INFESTED FRUIT

Overholser *et al* (1944) found that " Growth chemical sprays tend to result in the adherence on the trees of more codling moth infested pears, especially with larvæ in the calyx." Enzie and Schneider (1941), using replicated sprays of NAA and NA on Stayman Winesap (*99*), report that the " Results " for the infested fruits were " very similar to those secured for sound fruit." Although the materials were effective in reducing the drop of wormy fruits, the total percentage drop of these fruits was high. It therefore follows that these sprays did not appreciably increase the number of wormy fruits to be handled in the picking and grading process."

It is obvious that the sprays cannot alter the percentage of fruit infested by codling moth, as the infestation takes place before the growth substance sprays are normally put on. Infested fruit, however, normally drop early and relatively few are normally present on the tree at the time of picking. Retention of these fruit on the tree, as a result of the sprays, would be a disadvantage, as it would entail more labour during the subsequent sorting processes. Evidence on the retention of these fruit by the sprays is rather conflicting.

Evidence at East Malling tends to suggest that most infested fruit fall before the optimum picking date, whether sprayed or not.

2. EFFECT ON FRUIT INFECTED WITH BROWN ROT

Retention of fruit suffering from brown rot or other contagious diseases might be a considerable disadvantage, as it might lead to the spread of the disease, especially where the fruit was crowded or borne in clusters. Exact observations on this point seem to be lacking, but general observations at East Malling have shown that the proportion of unmarketable fruit, including both those infested with codling moth and those infected with brown rot, was usually less, if anything, on the sprayed than on the unsprayed trees. More work on this matter seems to be required. In particular, the rather faint possibility that the growth substances may actively increase resistance of the fruit to the spread of these diseases, should be examined.

3. EFFECT ON RESPIRATION AND PHOTOSYNTHESIS

The only work on the effect of growth substance sprays on respiration and photosynthetic activity of leaves seems to be that reported by Gardner *et al* (1940). These authors used "yearling York Imperial trees, growing in sand culture crocks with full nutrient solution." They report that " No significant differences occurred between treated and control trees in rate of respiration during an eight-day period, nor in the photosynthetic activity on three successive days, following application of the spray."

4. EFFECT ON YOUNG STEMS AND LEAVES AND OPEN BLOSSOM

Mitchell (1940), applying very great overdoses of naphthaleneacetic acid and the acetamide, in lanolin paste, to the stems of bean plants, obtained a development of tumours on the stems. No trace of any such disorder has been reported in fruit trees as a result of the normal doses of these substances used as sprays.

It has already been mentioned that sprays of either the acid or the acetamide, applied to the open blossom, reduce fruit set (Burkholder and McCown, 1940, and Schneider and Enzie, 1943) and that the acid, especially at relatively high concentrations of over ·001, tends to cause twisting and distortion in young leaves and stem when applied early in the season, though the acetamide has no such effect. No harmful effects have been reported by any worker where the materials have been applied at the usual concentrations at the appropriate time for the control of fruit drop.

5. EFFECT ON LEAF-FALL

It would be of considerable value if the growth substance sprays tended to prevent leaf-fall. Fruit are dependent on the leaves for much, if not all, of the materials they require

for growth. If the leaves fall before the fruits are picked, the latter cease to increase in size (Archbold, 1932). A partial defoliation, such as frequently occurs, before the fruits are ready to pick, must slow up the rate of growth. Gardner (1940) carried out "Rather extensive studies . . . to determine the effect of various growth substances on the subsequent persistence of apple leaf petioles." He found that the sprays undoubtedly had some effect, which was reflected in a greater force in grams necessary to pull the petiole from the shoots." Any such effect was, however, of short duration, and there was no evidence that sprayed trees held their leaves later into the season than the unsprayed. It is rather curious that the effect of growth substances on leaf fall should have led to the discovery of their effect on fruit drop, and yet the substances then found to have no effect on leaf fall in these trees. Batjer (1942a) found effect of NAA sprays on persistence of apple leaf petioles greater at high than at low temperatures.

6. EFFECT ON TIME OF BUD-BREAK IN FOLLOWING SPRING

Hitchcock and Zimmerman (1943) applied potassium a-naphthaleneacetate as a spray to apple, cherry, peach, pear and plum trees at concentrations of 200, 400 and 800 p.p.m., on three dates, July 21st, August 20th and September 17th and got a delay in bud opening the following season. "The delay . . . ranged from a few days to 14 days for flower buds and up to 19 days for vegetative buds, depending upon the concentration of KNA, and the time of application and the variety." For the cherry, a concentration of ·02 applied in July was as effective as one of ·04 applied in August or of ·08 applied in September. Peach and plum proved rather more sensitive than the cherry, the apple rather more resistant. The concentrations they found effective were much greater—more than 10 times as great—than those normally used for sprays to control pre-harvest drop, and it is doubtful if the lower concentrations would cause an appreciable delay in bud-break. Any delay, however, would clearly be of value, as it would lessen the danger of frost damage to blossoms in spring.

7. HARMLESSNESS TO ANIMALS

Before sprays can be used on fruit for human consumption, it is essential to know that they will be harmless to those consuming the fruit, especially as the fruit will be picked, and perhaps eaten, rather soon after the application of the spray. Gardner *et al* (1940) described experiments with treatment of animals with naphthaleneacetic acid which convinced them that the danger was very remote and reported that "No irritating or other disagreeable effects have been noted by workers applying the spray." Since then, Dr. Haddow, of the Chester Beattie Research Institute, has carried out a thorough trial with the pure substance, and with fruit of Millers Seedling sprayed with naphthaleneacetic acid at East Malling, and reports that "No carcinogenic or other harmful effect has been obtained in experiments with naphthaleneacetic acid carried out for more than a year." In view of these results and the very minute quantities of substances involved, use of these sprays on fruit for human consumption seems safe.

Part 5 · PRACTICAL RECOMMENDATIONS

A. OCCASIONS WHEN CONTROL IS REQUIRED

Control is of value where heavy losses are likely to occur before the fruit can be picked, or danger of such losses makes it necessary to pick the fruit before they are in their prime condition. Control is likely to be of particular value to growers who have a large acreage of a single variety, such as Worcester, and find it will take several weeks to complete the harvest; here only the trees to be picked last need to be sprayed.

On no account should sprays be used to retain fruit on the trees beyond the time when they ought to be picked. Sprays may prevent drop but do not prevent ripening; too long postponement of picking will result in over-maturity and loss of quality.

As incidence of drop varies greatly with climate, season and locality, only the individual grower can decide whether control is required in a particular block of trees. Where past experience has not provided the requisite knowledge, some indication can be obtained by clearing the ground under certain trees and watching for the incidence and severity of the drop.

B. VARIETIES WORTH SPRAYING

Some varieties of apples respond well, others are not worth treating. The most outstanding successes in the U.S.A. have been obtained with the summer varieties Williams, Early McIntosh and Duchess of Oldenburg, but good results have usually been obtained with Delicious, McIntosh, Stayman Winesap, Winesap and Rome Beauty ; late varieties, such as Baldwin and York Imperial, have rarely responded well. In England, the varieties, so far tried, which seem well worth spraying, are Beauty of Bath, Miller's Seedling and Worcester. Some growers have reported success with Ellison's Orange and Cox, but controlled experiments on Cox and Bramley have not been on a sufficient scale, or conclusive enough, to justify a recommendation that these should be sprayed.

Pears have usually responded well, especially Bosc in the U.S.A. and Williams Bon Chretien (Bartlett) in the U.S.A. and Australia. Conference has responded well in one experiment in England, but often seems to hold its fruit well until picking time.

Little success has been reported with stone fruit.

C. SUBSTANCES TO USE

If the pure chemical is to be used, naphthaleneacetic acid, or one of its salts, is to be preferred. The acetamide seems equally effective, but is more expensive and less soluble. The chemical must be dissolved in a little alcohol—methylated will do—before it is added to the water in the spray tank.

Most growers will find it more convenient to use one of the commercial preparations now on the market.

D. CONCENTRATION

The "standard" strength of 10 parts per million (0·001%) seems the best for most purposes and is the one recommended in the instructions issued by most makers. Sprays of half this strength have often given good results, especially with summer varieties and in hot weather.

E. QUANTITIES PER TREE

From 1 to 1½ gallons of spray should be applied for every estimated bushel of fruit. For example, if a tree is bearing 6 bushels, it should receive 6 to 9 gallons. If economy in material is essential, it is better to cut down the concentration rather than the quantity per tree. For a fruit stem hit by a weak spray may respond, one missed by a strong spray is unlikely to respond.

F. METHOD OF SPRAYING

It is essential to wet the fruit stems ; wetting the leaves is of little or no value. The spray should be directed, therefore, at the fruit rather than the foliage. Trees should be sprayed from within as well as from without, and from above rather than from below, as it is the stem end, and not the calyx end, that requires the spray. Particular care should be taken to wet the upper part of the tree thoroughly.

G. SUITABLE WEATHER FOR SPRAYING

Sprays are much more effective when applied in hot weather than in cool. If they have to be applied in the cool of an early morning, or on a cold day the concentration should be raised.

If rain is expected within a few hours spraying should not be done. Rain more than eight hours after spraying does not seem to reduce the effect.

H. TIME TO SPRAY

Sprays only remain effective for a limited period; this is from 10 to 14 days with McIntosh in the U.S.A. and up to three or four weeks with most varieties. The aim is to make this effective period cover the time of heaviest drop. Varieties that show a steady drop over a long period, like McIntosh towards the southern limit of its range in the U.S.A., do not benefit much from sprays. Varieties liable to a sudden severe drop, without warning, should be sprayed a few days ahead of the danger period; a second application two or three weeks later, as the first wears off, may be worth while if the danger remains. Varieties that hold their fruit well until picking time approaches, and then show a rapidly increasing drop, should be sprayed some 10 days before the picking date, or earlier if there are signs of sound fruit falling. Where the picking period is to be long and only the trees to be picked last are to be sprayed, the spray can be applied just before the first trees are picked.

J. SPREADERS

Spreaders do not seem to be of particular value, but are probably worth while where the water is hard. Summer oil, up to 1%, has occasionally increased efficiency.

K. COMPATIBILITY WITH OTHER SPRAYS AND RESIDUES

Pre-harvest sprays seem to be completely compatible with summer oil, mild fungicides and insecticides—such as derris—and with lead arsenate. Sprays containing lime seem sometimes to reduce the efficiency of the growth substance. Residues from such sprays, however, seem to be harmless, provided an interval of some four days between sprays is allowed.

L. SAFETY OF SPRAYS

No trace of any harmful effect from pre-harvest sprays on either the trees or on animals has been detected, and the danger of any such effect may be regarded as negligible.

TABLE 5

EXPLANATION OF TERMS USED

A serial number is given for cross reference from tables 1—4 and text.
INITIAL CROP = bushels per tree at time of treatment.
Initial Drop = bushels or percentage fruit dropped before treatment.
PICKING PERIOD normal = date or dates when commercial picking would have taken place.
optimum = date or dates when fruits were at the best condition for picking.
Values in parenthesis thus (17) are implied, rather than explicitly stated, in the original papers.

Abbreviations

A-LS = Ap-L-Set.
Alum. sulph. = aluminium sulphate.
B.M. = bordeaux mixture.
bu = bushels.
C.P. = commercial preparation (unnamed).
DPOA = 2-4-dichloro-phenoxy-acetic acid.
Frui. = Fruitone.
gal. = gallons.
h = heavy.
Ho.A = Hortomone A.
KNA and NaNA = the potassium and sodium salts of NAA.
L. = lime.
L.A. = Lead arsenate.
mat. = mature.
mod. = moderate.
NA = a-naphthalene acetamide.
NAA = a-naphthaleneacetic acid.
NAN = naphthalene acetonitrite
NaT = sodium thiocyanate.
ND. = no date given.
NMIT = naphthalene methyl isothiocyanate.
NMT = naphthalene methyl thiocyanate.
NOA = naphthoxyacetic acid
Parm. = Parmone.
Phyo = Phyomone.
p.p.m. = parts per million.
sm. = small.
Sta. = State.
StaF = Stafast
StDr. = StopDrop
T6A = tetralin-6-acetamide.
var. = variable.

TABLE 5.

Summary of selected results condensed from published papers on the control of fruit drop by

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initial Drop*	Picking Period : Normal *Optimum*	Experimental Treatments					
					Active Substance		Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
					Name	p.p.m.				
	ALLINGTON									
1	Swarbrick 1943 Long Ashton, England	 1942			NAA NOA	10 10		1 1	1/10 1/10	5 5
	BALDWIN									
2	Hoffman & al 1942 N.Y. Sta., U.S.A.	30 1941	23 bu *1-2 bu*		NAA NAA	10 10	as spray as dust	1 1	1/10 1/10	
3	Murphy, 1941 Rhode I., U.S.A.	 1940	 *v. few*	1-15/10	NAA	10		1	10/10	
	BEAUTY OF BATH									
4	Swarbrick, 1945 Long Ashton, England	20 1944		3-5/8 *10/8*	NAA NAA	15 15	1½ pints ester	1 1	18/7 18/7	5 5
5	Vyvyan, 1941 E Malling, England	9 1940	½ bu	24/7	NAA	5		1	24/7	
6	Vyvyan, 1946 E. Malling, England	15 1945	1½ bu *v. few*	16/7	NAA	10	Spreader	1	5/7	
7	Vyvyan, 1946 E. Malling, England	mat. 1945	4½ bu *v. few*	23/7	NAA	10		1	5/7	
	BRAMLEY SEEDLING									
8	Vyvyan, 1946 E. Malling, England	mat. 1942	 *h.*	6-17/10	NAA NAA NAA	6 6 6		2 1	14/9 2/10 2/10	4 2 2
9	Vyvyan, 1946 E. Malling, England	mat. 1943	7 bu	21-24/9	NAA NAA	7½ 7½	2 lb. L.A. Nil.	1 1	21/6 9/9	4 4
10	Vyvyan, 1946 E. Malling, England	mat. 1945	10½ bu *mod.*	27/9-9/10	NAA	10		1	7/9	
11	Vyvyan, 1946 E. Malling, England	mat. 1945	14½ bu *mod.*	29/9- 13/10	NAA		as dust	1	8/9	
	CALVILLE LESANS									
12	van Stuivenberg, 1941 Netherlands.	 1940			NAA	20		1	19/9	
	COX'S O. PIPPIN.									
13	Vyvyan, 1941 E. Malling, England	11 1940	1 bu	25/9	NAA	5	+1% oil.	1	24/7	1
14	Vyvyan, 1946 E Malling, England.	 1943	v. var.	17-19/9	NAA	5	+1 % oil.	1	12/7	
	DELICIOUS									
15	Batjer & al 1941 N.Y. Sta., U.S.A.	15 1940		25/9	NAA	10		1	11/9	(*11*)
16	Batjer, 1942b N.Y. Sta., U.S.A.	16 1941	mod.		NAA NAA	5 2½	at 85°F	1 1	9/9 9/9	
17	Burkholder & al 1941 Indiana, U.S.A.	18 1940	var.		C.P.	10		1	19/9	7
18	Burkholder & al 1941 Indiana, U.S.A.	28 1940			C.P.	10		1	13/9	(14)
19	Gardner & al 1940 Maryland, U.S.A.	 1939			NAA	5		1	29/9	

TABLE 5 Observations.

treatment with growth substances. N.B.—*For explanation of terms used see page* 51.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
1/10	26/10	16	8	Applied late, but 1942 was a late season.	1	23
1/10	26/10		11			
1/10	10/10	56	18	Applied rather late.	4	
1/10	10/10		19	Colour poor on 1/10.		
10/10	26/10	78	61	Applied very late, 4 C.P.s gave similar results.		25 32
18/7	3/8	30	4	Colour and quality greatly improved.		26 30
18/7	10/8	90	18			33 45
24/7	31/7	63	56	Sprayed much too late.	2	26 32
24/7	7/8	89	65	2½ p.p.m. gave 50 & 68%.		
5/7	16/7	91	23	Gale on 14-15/7. Fruit rather soft when picked.		29
5/7	23/7	69	9	Older trees in more sheltered position. Fruit less mature.		
15/9	2/10	9	4	NA gave similar results.	1. 3.	26
2/10	17/10	24	10			
2/10	17/10		15			
18/6	8/9	40	39	Applied during "June" drop. Control received L.A. alone.		26 31
10/9	21/9	21	14	Same trees: half each set resprayed.		42
12/9	5/10	18	16	Not significant.		26
13/9	8/10	20	20			39 43
19/9	17/10	18	6	Single tree; part sprayed, part control.		
19/9	24/10	46	13			
24/7	21/8	7	5	Diffs. significant. 1% oil alone gave 10% & 22% drop.		32 42
24/7	25/9	21	14			
12/7	19/9	22	17	Not significant. 1% oil alone gave 22% drop.		42
11/9	27/9	17	4	Less control from 5 or from 2½ p.p.m., from fewer gallons, and from NaNA and T6A.	1. 2.	23 23 26 26
11/9	11/10	68	17			36
9/9	(30/9)	16	5	Less control with spray applied when temp. was 64°F.	2	
9/9	(30/9)		7			26 28
19/9	5-6/10	28	10	From data in text. 70 trees sprayed and 70 control.		
13/9	27/9	22	5	From data in text.		
29/9	11/10	94	31	Few trees: limb treatment.		26

TABLE 5 continued.

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initial Drop*	Picking Period Normal *Optimum*	Experimental Treatments: Active Substance Name	ppm	Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
20	Gardner & al 1940 Maryland, U.S.A.	1939			NAA	20	on stem end only of fruit	1	26/9	
21	Greve & al 1941 Delaware, U.S.A.	1940			NAA C.Ps.	(10) (10)		1	13/9	
22	Kadow & al 1942 Delaware, U.S.A.	1941			Parm.	(10)	+Blackleaf 155 3 lb. 14%	1	N.D.	
23	Murneek 1940a Missouri, U.S.A.	1939		6-23/9	NAA	5		1	13/9	
24	Murneek 1940a Missouri, U.S.A.	1939		12-26/9	NA	10		1	14/9	15-30
25	Overholser & al 1943 Wash. Sta., U.S.A.	1941			NAA	10	+⅛% oil	1	13/9	
26	Overholser & al 1943 Wash. Sta., U.S.A.	1942			NAA NAA	10 10	+1% oil. +⅛% oil.	1 1	18/9 18/9	
27	Overholser & al 1943 Wash. Sta., U.S.A.	1942			NAA NAA	10 10	+1% oil. +1% oil.	1 1	19/9 19/9	
28	Overholser & al 1943 Wash, Sta., U.S.A.	1942			NAA NAA	10 10	+water after 2 hrs.	1 1	19/9 19/9	
29	Ruth & al 1944 Illinois, U.S.A.				KNA	10	+ L.A. & lime 3.3.100	1	22/9	
30	Whittaker & al 1944 N.S.W., Australia.	1943			NAA	10		1	23/2	
	DUCHESS OF OLDENBURG.									
31	Gardner & al 1940 Maryland, U.S.A.	1939			NAA NA	20 20	+L.A. & lime 3-6-100	1 1	7/7 7/7	
32	Hoffman 1941b N.Y. Sta., U.S.A.	1940	4½ bu		NAA	10		1	9/8	
33	Southwick, 1943 Mass., U.S.A.	1942			C.P.	10		1	5/8	
	EARLY McINTOSH									
34	Gardner & al 1940 Maryland, U.S.A.	1939			NAA NA	5 5		1 1	17/7 17/7	
35	Hoffman 1941b N.Y. Sta., U.S.A.	9 1940	4 bu *few*		NAA	10		1	9/8	
	EDWARD VII									
36	Berry & al 1942 L. Ashton, England	1941			NAA NAA	10 5		1 1	19/9 19/9	4 4
37	Swarbrick 1943 L. Ashton, England	1942	good *few*		NAA NOA	10 10		1 1	1/10 1/10	5
	FRAMBOOSAPPEL									
38	van Stuivenberg 1941 Netherlands	17 1940		10-12/10	NAA NAA	20 10		1 1	19/9 19/9	
	GOUDREINETTE									
39	van Stuivenberg 1941 Netherlands	1940		13-15/10	NAA	10		1	30/9	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
26/9	3/10	57	5	When applied to calyx end only, values for drop were 21 & 76%.		22
26/9	17/10	93	17			
13/9	23/9	26	8	C.P.s were Parm., Frui., A-LS. 5 p.p.m. gave 10% drop. Mean for all treatments.	2	25 26
15 days		10	1	L.A. + B.M., & alum. sulph. + lime each reduced control.		42 42
20 days		23	2			
13/9	25/9	58	9	Only 5 treated and 2 control trees.		26
13/9	6/10	84	24			
14/9	23/9	39	1	Few trees. NAA. at 10 & 5 p.p.m. gave less control.	1. 2.	23 26
14/9	5/10	66	2			
13/9	25/9	13	7	6 p.p.m. gave 9% & 3 p.p.m. gave 10% drop.	2	26 26
18/9	16/10	23	3	+ ¼% oil & 3 lb. L.A. gave 3% drop.		42
18/9	16/10		5			
19/9	16/10	25	6	Applied 7.0 a.m. at 42° F.		28
19/9	16/10		3	Applied 1.0 p.m. at 75° F.		
19/9	16/10	25	8	Water spray (sham rain) after 8 hours gave 7%, after 24 hours 9% drop.		29
19/9	16/10		13			
22/9	29/9	31	24	Less control with KNA & KNA + B.M. applied at lower temperatures.		23 42
29/9	5-6/10	59	9			
23/2	11/3	17	7			
23/2	26/3	47	35			
7/7	27/7	68	18	Less control from 10 p.p.m. alone & from 10 p.p.m. + 1% oil.	1	23 40
7/7	27/7		12			
9/8	16/8	5	1/3	" Spot-picked " on 17, 21 & 26/8.		
9/8	26/8	22	4			
7/8	11/8	20	4	Few trees. Correctly timed. Dust gave less control.	4	37
7/8	14/8	55	7			
17/7	29/7	78	5	NAA at 2½ p.p.m. gave 14% drop.	1. 2.	23 26
17/7	29/7		0	NA " " " " 13% "		
9/8	16/8	26	1½*	*Mean for 4 preparations ;		
9/8	26/8	43	10*	picked 17, 21 & 26/8 ; poor colour on 9/8.		
19/9	19/10	49	34	Gale on 18-19/10 caused heavy drop.	2	26 29
19/9	19/10		42			
1/10	26/10	9	9	Sprayed late, but 1942 was a late season.	1	23 29
1/10	26/10		9			
19/9	17/10	36	23	Each represents 1 tree ; part sprayed, part control.		
19/9	17/10	42	32			
30/9	14/10	16	13	Estimated from values for 5 control and 5 sprayed trees.		

TABLE 5 continued.

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initial Drop*	Picking Period: Normal *Optimum*	Experimental Treatments: Active Substance Name	Active Substance p.p.m.	Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
40	VAN STUIVENBERG 1941 Netherlands.	1940			NAA NAA NAA	5 10 10	+ casein + casein + shell	1 1 1	10/9 10/9 18/9	
41	GRAVENSTEIN HILTON & al 1943 Nov. Scot., Canada	30 1941	3½ bu *16%*		Phyo.	10		1	31/8	
42	GRIMES GOLDEN GREVE & al 1941 Delaware, U.S.A.	old 1940			NAA 3 C.P.s	10 10		1	18/9	10-26
43	GRONSVALDER KLUMPKE VAN STUIVENBERG 1941 Netherlands	old 1940		3-5/10	NAA	20	+ spreader	1	19/9	
44	JONATHAN BURKHOLDER & al 1941 Indiana, U.S.A.	30 1940			C.P.	10		1	N.D.	(15)
45	COLE & al 1941 Victoria, Australia.	1940	4 bu		NAA NAA	10 5		1 1	28/2 28/2	
46	ELLENWOOD & al 1942 Ohio, U.S.A.				NAA NAA	10 10		1 1	27/9 4/10	
47	OVERHOLSER & al 1942 Wash. Sta., U.S.A.	1941	*8%*		C.P.	10	+ spreader or oil	1	28/8	
48	OVERHOLSER & al 1942 Wash. Sta., U.S.A.	1940			(NAA)	5	+ spreader or oil	1	23/8	
49	STRICKLAND & al 1941 S. Austr., Australia.	1941	9-10 bu		NAA NAA NAA	20 20 20	+ trace citric acid	3	7/2 21/2 3/3	3½ 3½ 3½
50	WHITTAKER & al 1944 N.S.W., Australia.	1943			NAA	10		1	5/3	
51	KING DAVID GARDNER & al 1940 Maryland, U.S.A.	1939			NAA	5		1	29/9	
52	LEMOENAPPEL VAN STUIVENBERG 1941 Netherlands	27 1940		29-30/9	NAA	10		1	21/9	
53	VAN STUIVENBERG 1941 Netherlands	17 1940		29-30/9	NAA	10		1	21/9	
54	McINTOSH BATJER & al 1941 N.Y. Sta., U.S.A.	15 1940	10 bu	4/9	NAA NAA NAA	5 5 5		3	23/8 26/8 6/9	
55	BURKHOLDER & al 1941 Indiana, U.S.A.	15 1940			C.P.	(10)		1	30/8	(7)
56	ELLENWOOD & al 1942 Ohio, U.S.A.				(NAA) (NAA)	10 5		1 1		
57	ELLENWOOD & al 1942 Ohio, U.S.A.				(NAA) (NAA)	10 5		1 1	? ?	
58	GARDNER & al 1940 Maryland, U.S.A.	1939			NAA NAA	5 5	alone + ½% oil	1 1	23/9 23/9	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
10/9	14/10	6	10	Each represents values for 1 tree :—		
10/9	14/10	26	6	part tree sprayed, part control.		
10/9	14/10	19	39	Other trials gave similar results.		
31/8	14/9	11	2	Parmone had similar effect.		25 30
18/9	30/9	18	7	Mean for NAA, Frui., Parm. & St.Dr.		25
19/9	3/10	61	0	Single tree : part sprayed, part unsprayed.		
19/9	17/10	90	47			
N.D.	N.D.	19	17	From data in text.		
2/3	12/3	20	5		2	
2/3	12/3		4			26
27/9	21/10	19	9	2 sprays at 10 p.p.m. gave 8% (cited Batjer,	3	
27/9	21/10		8	1943).		34 34
28/8	3/10	3	2			
23/8	15/9	43	39	Applied to fruit & not to leaves.		22 26
7/2	21/2	4	3	C.P.s at 1 : 500 gave slightly better control.		
7/2	7/3	19	6	Gain about 1½ bu. per tree.		26 33
7/2	25/3	24	7			
5/3	19/3	15	8	Very little drop and no control until 12/3.		29
5/3	2/4	25	11			
29/9	11/10	52	11	Indolebutyric, acetic, and propionic acids gave less control.		22 26
21/9	6/10	22	9	Based on 2 control and 2 sprayed trees.		
21/9	6/10	20	7	Based on 3 control and 2 sprayed trees.		
23/8	4/9	39	3	Less control when 2nd spray applied after 2		
23/8	6/9	52	15	hour or 7 day interval.	3	36 36
23/8	10/9	72	58			
30/8	17—18/9	33	27	From data in text.		
N.D.	N.D.	19	6	2½ p.p.m. gave 9% drop (cited Batjer, 1943).	2	26 26
N.D.	N.D.		8			
N.D.	N.D.	31	13	2½ p.p.m. gave 17% drop (cited Batjer, 1943).	2	26 26
N.D.	N.D.		18			
23/9	5/10	33	19	Less effect from 2½ p.p.m. NAA, & from ⅛%		
23/9	5/10		13	oil.	2	26

TABLE 5 continued.

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initial Drop*	Picking Period; Normal *Optimum*	Experimental Treatments: Active Substance Name	p.p.m.	Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
59A	Gardner & al 1940				NAA	10*		1	6/9	
59B	Maryland, U.S.A.	1939			NAA	10		1	15/9	
60	Greve & al 1941				C.P.	10		2	15/8	
	Delaware, U.S.A.			*29/8*	C.P.	10			22/8	
61	Hilton & al 1943	30	4 bu	18/9	Phyo.	10		1	18/9	
	Nov. Scot. Canada.	1942		*13/10*	Phyo.	20		1	18/9	
62	Hilton 1944	31	mod - h		Parm.	20		1	6/10	
	Nov. Scot., Canada.	1943								
63	Hoffman 1941a	13	6.4 bu		NAA	10	alone	1	16/9	
	N.Y. Sta., U.S.A.	1940		*25/9*	NAA	10	+ ¼ % oil	1	16/9	
64	Hoffman 1941a	25	17½ bu		NAA	10		2	17/9	
	N.Y. Sta., U.S.A.	1940	*few*	*28/9*	NAA	10			23/9	
65	Hoffman 1941a	18	19½ bu		NAA	10		2	18/9	
	N.Y. Sta., U.S.A.	1940			NAA	10			26/9	
66	Hoffman 1941b	18			NAA	10		2	18/9	
	N.Y. Sta., U.S.A.	1940			NAA	10			26/9	
67	Hoffman 1941b	15	12 bu		NAA	5	alone	1	20/9	
	N.Y. Sta., U.S.A.	1940			NAA	10	+ ¼ % oil	1	20/9	
68	Hoffman & al 1942	16	16 bu		NAA	10		2	1/9	
	N.Y. Sta., U.S.A.	1941			NAA	10			5/9	
69	Hoffman & al 1943	17	23½ bu	—12/9	NAA	5		2	31/8	
	N.Y. Sta., U.S.A.	1942	*few*		NAA	5			5/9	
70	Hoffman & al 1943	35	27 bu		NAA	10		2	15/9	
	N.Y. Sta., U.S.A.	1942			NAA	10			18/9	
71	Murphy 1941				NAA	5		2	20/9	
	Rhode I., U.S.A.	1940			NAA	5			26/9	
72	Murphy 1942	22	10 bu		NAA	10		1	9/9	(13)
	Rhode I., U.S.A.	1941	*few*		NAA	10		1	11/9	(13)
					NAA	10		1	13/9	(13)
73	Overholser & al 1943				NAA	10	+ spreader or oil	1	16/8	
	Wash. Sta., U.S.A.	1940								
74	Overholser & al 1943				NAA	10	+ spreader or oil	1	20/8	
	Wash Sta., U.S.A.	1941								
75	Overholser & al 1943				NAA	10		1	16/8	
	Wash. Sta., U.S.A.	1940								
76	Southwick & al 1941b				NAA	10		2	12/9	
	Mass., U.S.A.	1940	(2%)		NAA	10			28/9	
77	Southwick & al 1941b				NAA	10		2	N.D.	
	Mass. U.S.A.	1940			NAA	10			+6.	
78	Southwick & al 1941b	young			NAA	10	+1 pt oil	1	28/9	
	Mass., U.S.A.	1940	*20%*							
79	Southwick & al 1941b	old			NAA	10	+ 1 pt oil	1	28/9	
	Mass., U.S.A.	1940	*30%*							

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
6/9	21/9	20	14*	*5 p.p.m. on 6/9 gave 16% drop.	2	
15/9	21/9	22	3	Sept. 6 too early, Sept. 15 right.		26 31
15/9	25/9	53	23			
15/8	22/8	19	7	Mean for Frui. & Parm.	2. 3.	
15/8	5/9	59	36	Less control from 1 spray at 10 p.p.m.		26 34
18/9	30/9	4	3	Similar effects from Parm.	3	25 34
18/9	13/10	13	2			45 46
6/10	15/10	5	2	Heavy drop from gale on 16-17/10. Sta-Fast gave similar results.		25 29 45
16/9	24-25/9	20	3	Picked too early. Similar values for NAA &		23 26 34
16/9	24-25/9		3	NA at 5 p.p.m.	1. 2. 3.	34 40
17/9	28/9	48	4	When 1st spray was at 5 p.p.m. drop was 6%. Good colour on 28/9.		33
18/9	25/9	20	2	1 spray (on 18/9) gave 9% drop by 1/10.		34
18/9	1/10	44	5			
18/9	25/9	13	2	Similar effect from NaNA at 10 p.p.m.	1	23 33
18/9	30/9	38	5			
20/9	26/9	24	8	Sprayed about 3 days too late.	1	23 40
20/9	26/9		4*	*3 different oils had same effect.		
1/9	5/9	10	4	Similar effect from single spray or dust.	3. 4.	34 37
1/9	9/9	23	5			
31/8	5/9	8	2	1 spray or dust at 10 p.p.m. on 31/8 gave 13%	2. 3. 4.	26 34
31/8	11/9	30	5	on 11/9.		36 37
15/9	18/9	3	2	Slightly less effect from 1 spray or dust or 2		
15/9	25/9	11	3	dusts.	3. 4.	34 37
20/9	30/9	19	5	Date of spraying more important than con-		
20/9	4/10	31	10	centration.	3	34
9/9	21/9	25	4	Applied on 3 dates ; each picked 12 days later.	2. 3.	26 31 34
(11/9)	23/9	29	7			34 34
(13/9)	25/9	32	9			
16/8	4/9	38	14	Only 4 sprayed & 6 control trees.		
20/8	2/9	17	9	Only 8 sprayed & 3 control trees.		
16/8	28/8	22	4	3 sprayed and 3 control trees.		
16/8	4/9	50	16		3	34
	up to 18/9	5	4	1st spray was too early. Less control when 2nd		26 34
	up to 5/10	66	29	was on 17/9.	2. 3.	34
N.D.	N.D.	20	3	1st spray alone gave 4% drop.	3	34
	up to 2/10	43	42	Includes initial drop of 20% ;		32
	up to 7/10	74	56	shows effect of very late spray.		
	up to 2/10	47	47	Includes initial drop of 30% ;		32
	up to 7/10	74	59	shows effect of very late spray.		

TABLE 5 continued.

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initial Drop*	Picking Period: Normal *Optimum*	Experimental Treatments: Active Substance Name	Active Substance p.p.m.	Spreader, Methods. etc.	No. oil Applns.	Dates applied.	Gals. per Tree
80A	Southwick & al 1941b				C.P.	10	alone	1	13/9	
80B	Mass, U.S.A.	1940			C.P.	10	+ oil	1	14/9	
80C					C.P.	10	alone	1	13/9	
81	Southwick 1942 Mass., U.S.A.	1941			C.P.	10		1	5/9	20-25
82	Southwick 1942 Mass., U.S.A.	1941			C.P.	10	+ 1 pt. oil	1	5/9	
83	Southwick 1942 Mass., U.S.A.	1941			C.P.	10	+ 1 pt. oil	1	19/9	
84	Southwick 1943 Mass., U.S.A.	1942		19/9	C.P.	10		2	8/9	
					C.P.	10			12/9	
85	Southwick, 1943 Mass., U.S.A.	1942	32 bu		C.P.	10	as spray	1	3/9	30
					C.P.	10	as dust	1	3/9	(30)*
86	Southwick, 1944 Mass., U.S.A.	1943			NAA	20		1	9/9	
	MILLERS SEEDLING									
87	Vyvyan, 1942 E. Malling, England.	mat. 1941	3¼ bu	28/8	NAA	10		1	7/8	2
	MILTON									
88	Bryden, 1941 N.S.W., Australia	1941			C.P.		+ 1 pt. oil	1	24/1	
	NORTHERN SPY									
89	Hoffman & al 1942 N.Y. Sta., U.S.A.	30 1941	19 bu		NAA	10		1	4/10	
90	Roberts & al 1943 Wisconsin, U.S.A.	1942			A-LS	2½		1	4/10	
91	Roberts & al 1943 Wisconsin, U.S.A.	1942			A-LS	2½		1	12/10	
	RED GRAVENSTEIN									
92	Strickland & al 1941 S. Austr. Australia.	sm 1941			NAA	20	+4 pts.	3	10/1	2
					NAA	20	oil & trace		28/1	2
					NAA	20	citric acid		18/2	2
	RIBSTON PIPPIN									
93	van Stuivenberg 1941 Netherlands.	17 1940		3-5/10	NAA	10	+ shell	1	18/9	
					NAA	10	+ shell	1	18/9	
	ROME BEAUTY									
94	Burkholder & al 1941 Indiana, U.S.A.	25 1940	*few*		C.P.	10		1	13/9	
					C.P.	10		1	20/9	
95	Gardner & al 1940 Maryland, U.S.A.	1939			NAA	5	+ ¼ % oil & citric acid	1	6/10	
	STAYMAN WINESAP									
96	Batjer & al 1941 Maryland, U.S.A.	9 1940	*nil*	16/10 *18/10*	NAA	10		1	11/9	
					NAA	10		1	20/9	
97	Ellenwood & al 1942 Ohio, U.S.A.				NAA	10		1	11/10	
					NAA			1	16/10	
98	Ellenwood & al 1943 Ohio, U.S.A.	1942			C.P.	(10)		1	5/10	
					C.P.	(10)		1	9/10	
					CP..	(10)		1	13/10	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
13/9	2/10	16	12	Examples of tests in commercial orchards.	2	26
14/9	2/10	24	13	Weaker sprays had less effect.	2	
13/9	23/9	19	4		2	26
up to	8/9	6	11	Less effect from 10 p.p.m.	4	
8/9	17/9	*210**	*65**	*As per cent. drops up to 8/9.		
up to	8/9	12	11	Less effect from 10 p.p.m.	4	
8/9	19/9	*141**	*85**	*As per cent. drops up to 8/9.		
up to	22/9	26	24	Example of effect of a late application.		
22/9	26/9	19	7			
11/9	19/9	26	5	Less control from 1 application of spray & from		26 28 34
11/9	21/9	37	8	1 or 2 of dust.	2. 3. 4.	34 37
5/9	15/9	25	8	Dusted under ideal conditions.	4	
5/9	15/9		11	*Equivalent to 30 gallons.		37
9/9	13/9	6	2	Less control from 1 or 2 applications of spray at		
9/9	21/9	18	4	10 p.p.m. & from dusts.	2. 4.	37
7/8	28/8	32	16	5 p.p.m. gave slightly less control.	2	26 44
7/8	3/9	66	37	Sprayed fruit developed high colour.		
24/1	6/2	14	5	Gales on 25/1 & 2/2. Maturity not affected by spray.		
4/10	11/10	16	1	Control picked on 11/10.		
4/10	13/10		1	Gale on 9-11/10.		29
4/10	14/10	71	22	Values on 10/11 were 94% drop (control) & 78%		26 28
4/10	23/10	92	39	drop (sprayed). Frosty weather.		32
12/10	14/10	45	6	Values on 10/11 were 84% drop (control),		26 28
12/10	23/10	79	37	67% drop (sprayed). Frosty weather.		32
10/1	28/1	40	17	C.P. at 1 : 500 gave as good effect.		
10/1	18/2	80	40			26 33
10/1	24/2	90	48			
18/9	17/10	67	15	These are values for 2 trees ; each part sprayed,		
18/9	17/10	87	18	part control.		
13/9	5/10	16	6	From data in text. Trees sprayed from		
20/9	5/10	21	8	" within " and from " without."		
6/10	21/10	55	6	Gale on 21-22/10. Less control without citric		20 23 26
21/10	22/10	65	22	acid & from esters.		29 40 40
11/9	16/10	39	15	5 p.p.m. gave 16 & 12% drop.	2	26 31
11/9	16/10		7	Colour good by 18/10.		
11/10	30/10	38	40	2 sprays—1 on each date—gave 20% drop	3	34 34
11/10	30/10		22	(cited Batjer, 1943).		
5/10	18/10	68	23	Heavy drop from unsprayed on 10-11/10.		
9/10	18/10	63	29			
13/10	18/10	32	38			

TABLE 5 continued.

Serial number.	Variety Author Locality	Age Year	Initial Crop *Initivl Drop*	Picking Period: Normal *Optimum*	Experimental Treatments: Active Substance Name	p.p.m.	Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
99	Enzie & al 1941 N. Mexico, U.S.A.	14 1940	 *some*	30/9	NAA NAA	10 10		2	26/8 10/9	25 25
100	Gardner & al 1940 Maryland, U.S.A.	 1939			NAA NAA	5 5	alone + Bentonite	1 1	5/10 5/10	
101	Greve & al 1941 Delaware, U.S.A.	 1940	heavy		NAA C.P.	10 5		1 1	3/10 3/10	
	STERAPPEL									
102	van Stuivenberg 1941 Netherlands	17 1940	 *v. few*	25-27/9	NAA NAA NAA	10 10 15	+ casein + shell + shell	3	9/9 16/9 27/9	
103	van Stuivenberg, 1941 Netherlands	17 1940	 *v. few*	24-27/9	NAA NAA	5 5	+ casein +shell	2	9/9 30/9	
104	van Stuivenberg, 1941 Netherlands.	 1940		29-30/9	NAA	10		1	21/9	
	U.S.D.A.9.									
105	Gardner & al 1940 Maryland, U.S.A.	 1939			NAA NA	5 5		1 1	19/7 19/7	
	WEALTHY									
106	Hoffman 1941b N.Y.Sta., U.S.A.	14 1940	5 bu.		NAA NAA	5 5	 + ¼% oil	1 1	13/9 13/9	
107A *107B*	Southwick & al 1941b Mass., U.S.A.	 1940			NAA NAA	10 10		1 1	4/9 4/9	
108	Southwick 1943 Mass., U.S.A.	 1942			NAA	40		1	20-21/8	(30)
109	Southwick, 1943 Mass., U.S.A.	 1942		5/9	C.P.	(20)	as dust	1	21/8	
	WILLIAMS E. RED									
110	Batjer & al 1941 Maryland, U.S.A.	14 1940	8-9 bu		NAA NAA	10 10		1 1	16/7 16/7	10 10
111	Batjer 1942b Maryland, U.S.A.	 1941			NAA NAA	2½ 2½	at 83°F at 63°F	1 1	10/7 10/7	
112	Gardner & al 1940 Maryland, U.S.A.	 1939			NAA NAA	10 10		2	10/7 N.D.	
113	Greve & al 1941 Delaware, U.S.A.	 1940			NAA C.P.s	(10) (10)		1 1	19/7 20/7	
114	Hoffman 1941b N.Y. Sta., U.S.A.	18 1940	10 bu *v. few*	*16/8*	NAA NA	10 10		1 1	6/8 6/8	
115	Hoffman 1941b NY. Sta., U.S.A.	18 1940	6 bu		NAA NaNA	10 10		1 1	9/8 9/8	
116	Hoffman & al 1942 N.Y. Sta., U.S.A.	19 1941	7 bu		NAA NAA	10 10	as spray as dust	1 1	29/7 29/7	
117	Kadow & al 1942 Delaware, U.S.A.	 1941			Parm. Parm.	5 5	+ Blackleaf +LA,L,$CuSO_4$	1 1	N.D. N.D.	
118	Kadow & al 1942 Delaware, U.S.A.	 1941			Frui. Frui.	2½ 2½	alone +alum. suph. L.	1 1	N.D. N.D.	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				Remarks	References	
Period From	To	Control	Treated		Table	Text p.
28/8	10/9	15	5	10 p.p.m. NA gave 6 & 42% drop.	1	23 33
28/8	30/9	59	33	Sandy loam, pH 8.0, alt. 3,900 ft.		47
5/10	23/10	61	23	Effect of bentonite not significant.		
5/10	23/10		21			39
3/10	18-19/10	27	12	Mean values for A-LS, Frui., NAA, Parm.,	2	25 26
3/10	18-19/10		12	St. Dr.		
9/9	16/9	4	7	Based on weights, not numbers. Only 1 tree		
9/9	27/9	32	14	per treatment. Several similar experiments.		29
9/9	4/10	57	27			
9/9	30/9	44*	17	*Casein alone gave 35% and 47% on 30/9 &		
9/9	4/10	61*	26	4/10 respectively.		29
21/9	3/10	44	18	Based on 3 control & 3 sprayed trees.		
19/7	26/7	80	12	NAA & NA at 2½ p.p.m. gave 40 & 31% drop.	1. 2.	23 26
19/7	26/7		22			
13/9	22/9	28	9*	*Mean for 3 preparations; NaNA gave 8%	1	23 26
13/9	22/9		9	drop.		40
4/9	20/9	37	22	Values for 2 orchards.	2	
4/9	19/9	30	12	5 p.p.m. had less effect.	2	26
22/8	5/9	22	4	20 p.p.m. gave 8% and 40%.	2. 4.	26 37
22/8	10/9	52	16	10 p.p.m. C.P.s had less effect.		44
21/8	5/9	30	18	2 applications (21/8 & 29/8) at 20 p.p.m. gave	4	
21/8	10/9	64	52	18 & 53% drop.		
16/7	25-29/7		2	NOA, NAN, NMT, NMIT, NaT had no effect		23 23 23
16/7	25-29/7			T6A at 20 p.p.m. gave 18% drop.	1. 2.	26 41
10/7	21/7	13	2	1¼ p.p.m. at 83°F. & 63°F. gave 4% and 5%	2	
10/7	21/7		4	drop respectively.		25 28
10/7	25/7	79	2	6 sprayed & 6 control trees.		33
19/7	30/7	47	6	Mean for NAA, Frui., Parm., St. Dr. Two		
20/7	30/7	47	13	orchards.		24
6/8	16/8	74	½	Mean for 3 preparations. Colour extra-fancy	1	23
6/8	16/8		1	on 16/8.		
9/8	16/8	56	1	Sprayed 3 days late.	1	23
9/8	16/8		1			
29/7	9/8	82	2	4 trees per treatment.	4	37
29/7	9/8		2	Temperature at application 72°F.		
N.D.	+ 7	31	4	Mild sprays, e.g., Derris, did not reduce control		26 42
N.D.	+ 7		12	of drop.		42
N.D.	+ 7	24	8	*Aluminium sulphate 3 lb., lime 20 lb.		26
N.D.	+ 7		12			

TABLE 5 continued.

Serial number.	Variety Author Locality.	Age Year	Initial Crop *Initial Drop*	Picking Period Normal *Optimum*	Experimental Treatments: Active Substance Name	p.p.m.	Spreader, Methods. etc.	No. oil Applns.	Dates applied.	Gals. per Tree
	WINESAP									
119	Batjer & al 1945 N.Y. Sta., U.S.A.	1944			DPOA	10		1	N.D.	
120	Murneek 1940a Missouri, U.S.A.	1939		28/9-7/10	NAA	10		1	14/9	
121	Overholser & al 1942 Wash. Sta., U.S.A.	1941	8%		C.P.	10	+ oil or spreader	1	24/9	
122	Overholser & al 1943 Wash. Sta., U.S.A.	1941			NAA	10		1	24/9	
123	Overholser & al 1943 Wash. U.S.A.	1941			NAA	10	+ Vatsol 1:5000	1	24/9	
124	Overholser & al 1943 Wash. Sta., U.S.A.	1942			NAA NAA NAA	10 10 10	+ ¼ lb. $ZnSO_4$ + ¼ lb. lime + $ZnSO_4$ &lime	1 1 1	6/10 6/10 6/10	
	WORCESTER									
125	Swarbrick 1945 L. Ashton, England.	1944		—15/9	NAA	20		1	21/8	
126	Vyvyan 1941 E. Malling, England.	mat 1940	1¼ bu	6/9	NAA	2½		1	17/8	
127	Vyvyan 1946 E. Malling, England.	mat 1943	5 bu	12/8-3/9	NAA	10		1	17/8	5
128	Vyvyan 1946 E. Malling, England.	mat 1945	6 bu	—31/8	NAA	10		1	13/8	
	YELLOW TRANSPARENT									
129	van Stuivenberg 1941 Netherlands.	17 1940	good		NAA	10		1	19/7	
	YORK IMPERIAL									
130	Gardner & al 1940 Maryland, U.S.A.	1939			NAA	5		1	5/10	
	PEARS.									
	d'ANJOU									
131	Overholser & al 1943 Wash. Sta., U.S.A.	1940			NAA NAA	5 10	+ spreader or oil	1 1	11/9 14/9	
	BOSC.									
132	Overholser & al 1943 Wash Sta., U.S.A.	1940			NAA NAA	5 5	+ spreader or oil	1 1	11/9 14/9	
	COMTESSE DE PARIS									
133	van Stuivenberg 1941 Netherlands	1940			NAA	10		1	19/9	
	CONFERENCE									
134	Vyvyan 1943 E. Malling, England.	1942		25/9	NAA	4		1	14/9	
135	Vyvyan 1946 E. Malling, England.	1943		10/9	NAA	5		1	16/8	
	ST. REMY.									
136	van Stuivenberg 1941 Netherlands.	1940			NAA	10		1	23/9	
137	van Stuivenberg 1941 Netherlands.	20 1940			NAA	10		1	27/9	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
N.D.	+ 19	54	18	10 p.p.m. NAA alone gave 30 & 62% drop.	1	25 30
N.D.	+ 28	73	25	NAA + Carbowax gave 13 & 41%.		39
14/9	7/10	33	7	Severe gale on 8/10.	1	23
14/9	14/10	63	45	NA gave 10 and 41% drops.		
24/9	10/10	16	2			
24/9	13/10	17	2	6 p.p.m. & 3 p.p.m. gave 9% drops.	2	26 26
24/9	11/10	15	2	⅛% oil and " no spreader " gave 3% drop.		39
6/10	5/11	54	8	⅛% oil gave 12% drop. Only 2 half-tree units per treatment.		42
6/10	5/11		15			
6/10	5/11		8			
21/8	26/9	80	45	No control from NOA or DPOA. Quality on 26/9 very good.	1	23 25 29 45 46
17/8	30/8	6	4	5 p.p.m. gave 4 & 7% drops.	2	
17/8	6/9	14	6			26
17/8	2/9	18	4	Gain was about 1½ bushels per tree.		
17/8	7/9	44	13			
13/8	31/8	59	23	Same trees as those used in 1943.		
19/7	7/8	66	26	Single tree ; 2 control & 2 sprayed branches.		
5/10	23/10	41	14			26
11/9	22/9	2	1			
14/9	30/9	1	1			
11/9	22/9	14	2			26
14/9	30/9	19	7			
19/9	8/10	(20)	(7)	Estimated from values for 5 control & 5 sprayed trees.		
19/9	23/10	(43)	(13)			
21/9	25/9	2	0	*Includes 2-3% unsound fruit.		26
21/9	8/10	21*	5*			
16/8	10/9	3	5	Difference not significant. Ho.A gave similar result.		
24/9	5/10	(5)	(4)	Estimated from values for 3 control & 9 sprayed trees. Gale on 6/10.		29
24/9	7/10	(21)	(10)			
24/9	14/10	(27)	(11)			
27/9	22/10	61	25	Based on weights : 8 control and 3 sprayed trees.		

TABLE 5 continued.

Serial number.	Variety Author Locality.	Age Year	Initial Crop *Initial Drop*	Picking Period Normal *Optimum*	Experimental Treatments: Active Substance Name	p.p.m.	Spreader, Methods. etc.	No. of Applns.	Dates applied.	Gals. per Tree
	WILLIAMS (Bartlett)									
138	Bryden. 1941				C.P.		alone	1	24/1	
	N.S.W., Australia	1940			C.P.		+ 1 pt. oil	1	24/1	
139	Davey & al 1943		h.		NAA	10	+3 lb. L.A.	1	9/7	7½
	California, U.S.A.	1940	*some*		NA	10		1	9/7	7½
140	Davey & al 1943				NAA	10	+ 4 lb. L.A. &	1	3/7	
	California, U.S.A.	1941	*few*		NAA	5	3 qts oil	1	3/7	
141	Davey & al 1943				NAA	10		1	5/8	
	California, U.S.A.	1940			Frui.	10		1	5/8	
142	Strickland & al 1941			17/2	NAA	20	+ 4 qts oil	3	20/1	
	S. Austr. Australia	1941			NAA	20	+ 4 qts oil		4/2	
					NAA	20	+ 4 qts oil		17/2	
143	Whittaker & al 1944				NAA	10		1	19/1	
	N.S.W. Australia	1943								
	STONE FRUIT.									
	STEWART APRICOT.									
144	Hesse & al 1943	13	mod.		NAA	10	+ ¾% oil	2	27/4	7½-
	California, U.S.A.	1940	*few*		NAA	10			8/5	10
145	Hesse & al. 1943	14	mod.		NAA	5		1	5/5	7½-
	California, U.S.A.	1941	*v. few.*							10
	ELBERTA PEACH.									
146	Hesse & al 1943	old	v. var	31/7—11/8	NAA	(10)	Vapo-dust	1	10/7	
	California, U.S.A.	1941	*none*		NAA	(10)	Vapo-dust	1	10/7	
147	Hesse & al 1943				NAA	10	+ Vatsol OTC	1	11/7	
	California, U.S.A.	1941			Parm.	10		1	11/7	

TABLE 5. Observations—continued.

Accumulated Percentage Drops				REMARKS	References	
Period From	To	Control	Treated		Table	Text p.
24/1	6/2	13	3	Sprayed fruits were a deeper green & seemed less mature.		40 44
24/1	6/2		8			
9/7	25/7	*198*	*135*	*Numbers* (not percentages) dropped per tree. Fruitone gave *132*.	1	23 25
9/7	25/7		*73*			
3/7	31/7	20	13	Initial crop about 900 fruits per tree.	2	25
	&14/8		13			
9/8	29/8	*45*	*16*	Drops *after* 9/8 expressed as percentages of drops *before* 9/8.		
9/8	29/8		*17*			
20/1	4/2	10	8	1st application seemed too early. 2nd about right.		26 33
20/1	17/2	41	9			
20/1	3/3	63	*27*			
19/1	2/2	5	1	NAA + 1 pint oil gave similar result.		
19/1	12/2	16	4			
27/4	8/5	8	6	Effect due mainly to 1st spray.	1	22 29
27/4	1/6	25	8	NA gave less control of drop.		
5/5	26/5	25	15	From data in text. Little effect during first week.		22 29
						22 25
10/7	31/7	(10)	(8)	Values estimated from graph.		39
10/7	31/7		(7)	Little control after 31/7.		
11/7	30/7	*5465*	*4504*	*Numbers* (not percentages) dropped from 40 trees per treatment.		22 25
11/7	30/7		*4890*			

LITERATURE CITED

N.B.—Figures in italics at the end of certain references refer to serial numbers in the tables.

ARCHBOLD, H. K. (1932). Chemical studies in the physiology of apples. XII. Ripening processes in the apple and the relation of time of gathering to the chemical changes in cold storage. *Ann. Bot. Lond.*, 46 : 407-59, bibl. 67.

ASAMI, Y. (1941). Effectiveness of growth substances in preventing fruit drop. *J. hort. Ass. Japan*, 12 : 1-10, bibl. 20.

BAILEY, R. M. (1941). Hormone spray on apples to prevent excessive drop at harvest time. *Bull. Maine agric. Exp. Stat.*, 405, pp. 402-5.

BARNELL, E. (1939). Studies in tropical fruit. V. Some anatomical aspects of fruit fall in two tropical arboreal plants. *Ann. Bot. Lond.*, 3 : 77-89.

BATJER, L. P. (1941). Spraying to control pre-harvest drop of apples. *Proc. 86th annu. Meeting New York hort. Soc.*, pp. 184-91. *15, 54.*

——— (1942a). How are fruit drop sprays performing and what is the best way to use them ? *55th Trans. Peninsula hort. Soc., 1941*, pp. 29-31.

——— (1942b). Temperature in relation to effectiveness of pre-harvest drop sprays on apples. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 45-8. *16, 111.*

——— (1943). Harvest sprays for the control of fruit drop. *Circ. U.S. Dep. Agric.* 685, pp. 16, bibl. 23.

———, and MARTH, P. C. (1941). Further studies with sprays in controlling pre-harvest drop of apples. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 1945, 111-16. *15, 54, 96, 110.*

——— (1945). New materials for delaying fruit abscission in apples. *Science*, 101 : 363. *119.*

BERRY, W. E., and SWARBRICK, T. (1942). The influence of alpha-naphthaleneacetic acid sprays on the pre-harvest drop of apples under different systems of pruning. *A. R. Long Ashton agric. hort. Res. Stat. for 1941*, pp. 19-22, bibl. 3. *36.*

BLAIR, D. S. (1940). Harvest sprays. *47th A. R. Quebec pomol. fruitgr. Soc.*, p. 11.

BLASBERG, C. H. (1943). The relation of size of McIntosh flower buds to the production of fruit. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 220-3, bibl. 3.

BOWMAN, F. T. (1940). Controlling the cropping of pome fruits. New practices needed *Fruit Cult. N.S.W.*, 10 : 126 : 4, 22-3.

——— (1941a). The effective period for controlling fruit cropping. *J. Aust. Inst. agric. Sci.*, 7 : 56-60, bibl. 11.

——— (1941b). The influence of early times of fruit removal on the growth and composition of alternate-bearing sugar prune trees with special reference to blossom-bud formation. *J. Pomol.*, 19 : 34-77, bibl. 55.

BRADBURY, D. (1929). A comparative study of the developing and aborting fruits of *Prunus Cerasus*. *Amer. J. Bot.*, 16 : 525-42.

BRYDEN, J. D. (1941). Prevention of pre-harvest drop of apples and pears by the use of hormone sprays. *Agric. Gaz., N.S.W.*, 52 : 234. *88, 138.*

BURKHOLDER, C. L., and MCCOWN, M. (1941). Effect of scoring and of a-naphthaleneacetic acid and amide spray upon fruit set and of the spray upon pre-harvest fruit drop. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 117-20. *17, 18, 44, 55, 94.*

CHRISTOPHER, E. P., and PIENIAZEK, S. A. (1943). A further evaluation of hormone sprays. *Proc. Amer. Soc. hort. Sci. for 1943*, 43 : 51-2.

COLE, C. E., and MCALPIN, D. M. (1941). The pre-harvest " drop " of fruit. Reduction by spraying. *J. Dep. Agric. Vict.*, 39 : 213-7, also *Fruit World and Mark. Grower*, 42 : 6 : 6. *45.*

CRANE, M. B. (1923). Report on tests of self-sterility and cross-incompatibility in plums, cherries and apples at the John Innes Horticultural Institution. II. *J. Pomol.*, 3 : 67-84.

———, and BROWN, A. G. (1937). Incompatibility and sterility in the sweet cherry, *Prunus avium L.* *J. Pomol.*, 15 : 86-116.

DAVEY, A. E., and HESSE, C. O. (1943). Experiments with sprays in the control of pre-harvest drop of Bartlett pears in California. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 49-53, bibl. 2. *139, 140, 141.*

DETJEN, L. R. (1926). Physiological dropping of fruit. *Bull. Delaware agric. Exp. Stat.*, 143, pp. 36, bibl. 53.

DORSEY, M. J. (1919). A study of sterility in the plum. *Genetics*, 4 : 417-88.

ELLENWOOD, C. W., and HOWLETT, F. S. (1942). Pre-harvest sprays in 1940 and 1941. *Bimo. Bull. Ohio Agric. Exp. Stat.*, 27 (216) : 100-6. (Cited Batjer 1943). *46, 56, 57, 97.*

————, ———— (1943). Pre-harvest sprays in Ohio in 1942. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 193-7, bibl. 2. *98.*

ENZIE, J. V., and SCHNEIDER, G. W. (1941). Spraying for control of pre-harvest drop of apples in New Mexico. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 99-103. *99.*

FRASER, S. (1924). American Fruit. *Orange Judd Publishing Co., N. York*, pp. 885.

GARDNER, F. E. (1940). Control of the pre-harvest drop of apples by spraying with plant hormones. *Proc. 85th annu. Meeting New York hort. Soc.*, pp. 94-105.

————, MARTH, P. C., and BATJER, L. P. (1939). Spraying with growth substances to prevent apple fruit dropping. *Science*, 90 : 208-9.

————, ————, ———— (1940). Spraying with plant growth substances for control of the pre-harvest drop of apples. *Proc. Amer. Soc. hort. Sci. for 1939*, 37 : 415-28, bibl. 11. *19, 20, 31, 34, 51, 58, 59a, 59b, 95, 100, 105, 112, 130.*

GAYNER, F. C. H. (1941). Studies in the non-setting of pears. V. The size of flower in relation to its position in the truss. *A. R. E. Malling Res. Stat. for 1940*, A24, pp.41-43, bibl. 3.

GOODHUE, L. D. (1942). Insecticide aerosol production, spraying solutions in liquified gases. *Indust. Engng. Chem.* (industrial edition), 34 : 1456.

———— (1944). Insectical aerosols. *J. econ. Ent.*, 37 : 338-41.

GREVE, E. W., KADOW, K. J., and GUY, H. G. (1941). The prevention of the pre-harvest drop of apples by spraying. *54th Trans. Peninsula hort. Soc. for 1940*, pp. 53-61, bibl. 4. *21, 42, 60, 101, 113.*

GUSTAFSON, F. G. (1942). Parthenocarpy : natural and artificial. *Bot. Rev.*, 8 : 599-654, bibl. 174.

HALLER, M. H. (1943). Effect of pre-harvest drop sprays on the storage quality of apples. *Proc. Amer. Soc. hort. Sci. for* 1943, 42 : 207-10, bibl. 3.

HAMNER, C. L., SCHOMER, H. A., and GOODHUE, L. D. (1944). Aerosol, a new method of applying growth regulators to plants. *Science*, 99 : 85.

HATTON, R. G. (1927). The influence of different rootstocks upon the vigour and productivity of the variety budded or grafted thereon. *J. Pomol.*, 6 : 1-28.

HEINICKE, A. J. (1917). Factors influencing the abscission of flowers and partially developed fruits of the apple. (*Pyrus malus.*) *Bull. Cornell Agric. Exp. Stat.*, 393, pp. 114, bibl. 51.

HESSE, C. O., and DAVEY, A. E. (1943). Experiments with sprays in the control of fruit drop of apricot and peach. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 55-62. *144, 145, 146, 147.*

HILTON, R. G. (1944). A further note on pre-harvest spraying and delayed picking of McIntosh apples. *A. R. Nova Scotia Fruit Grow. Ass. for 1943*, pp. 95-101. *62.*

————, and SPURR, C. (1943). The influence of late picking on McIntosh apples. *A. R. Nova Scotia Fruit Grow. Ass. for 1942*, pp. 87-96. *41, 61.*

HITCHCOCK, A. E., and ZIMMERMAN, P. W. (1941). The use of naphthaleneacetic acid and its derivatives for preventing fruit drop of apple. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 104-10, bibl. 8.

————, ———— (1943). Summer sprays with potassium a-naphthalene acetate retard opening of buds on fruit trees. *Proc. Amer. Soc. hort. Sci. for 1942*, 42 : 141-5, bibl. 3.

HOFFMAN, M. B. (1941a). Some results in controlling the pre-harvest drop of McIntosh apples. Preliminary report. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 97-8. *63, 64, 65.*

———— (1941b). Controlling the pre-harvest drop of apples. *Bull. Cornell agric. Exp. Stat.*, 766, pp. 18, bibl. 12. *32, 35, 63, 64, 66, 67, 106, 114, 115.*

———— (1942). Blossom sprays to take apples off and harvest sprays to hold them on. *Proc. 87th annu. Meeting New York Stat. hort. Soc.*, pp. 172-9. *2.*

————, Van Doren, A. and Edgerton, L. J. (1943). Further tests on the methods of applying naphthaleneacetic acid for control of pre-harvest drop of McIntosh apples. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 203-6, bibl. 3. *69, 70.*

————, Edgerton, L. J., and Doren, A. van (1942). Some results in controlling pre-harvest drop of apples. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 35-8, bibl. 4. *2, 68 89, 116.*

Howlett, F. S. (1943). Di-nitro-compounds employed as sprays to reduce fruit set in the apple. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 151-8, bibl. 3.

Kadow, K. J., and Hopperstead, S. L. (1942). The compatibility of fruit drop chemicals. *55th Trans. Peninsula hort. Soc., 1941*, pp. 32-4, bibl. 5. *22, 117, 118.*

Kidd, F. (1934). The respiration of fruits. *Paper given before Roy. Inst. Great Britain, Nov. 9th, 1934*, pp. 33.

———— (1935). Respiration of fruits. *Nature*, 135 : 327-30.

————, and West, C. (1937). The keeping qualities of apples in relation to their maturity when gathered. *Sci. Hort.*, 5 : 78-86.

————, ———— (1938). Individual variation in apples. *Rep. Fd. Investn. Bd. Lond. for 1937*, pp. 114-5.

Lewis, D. (1942). Parthenocarpy induced by frost in pears. *J. Pomol.*, 20 : 40-1, bibl. 6.

Lloyd, F. E. (1913-4). Injury and abscission in *Impatiens sultani*. *Reprinted from 6th Rep. Quebec Soc. for protection of plants*, 8 pp.

———— (1927). Abscission in general and with special reference to the curtailment of fruitage in *Gossypium*. *Mem. New York hort. Soc.*, 3, pp. 195-207, bibl. 36.

McCown, M. (1943). Anatomical and chemical aspects of abscission of fruits of the apple. *Bot. Gaz.*, 105 : 212-20.

———— (1939). Abscission of flowers and fruits of the apple. *Proc. Amer. Soc. hort. Sci. for 1938*, 36 : 320.

————, and Burkholder, C. L. (1940). Very dilute a-naphthaleneacetic acetic acid spray fruit drop. *Proc. Amer. Soc. hort. Sci. for 1939*, 37 : 429-31, bibl. 1.

MacDaniels, L. H. (1937). Some anatomical aspects of apple flower and fruit abscission. *Proc. Amer. Soc. hort. Sci. for 1936*, 34 : 122-9, bibl. 1.

Meter, R. A. van, and Shaw, J. K. (1940). Apple varieties in Massachusetts. *Ext. Leafl. Mass. Stat. Coll. Ext. Serv.*, 42 (revised), pp. 20.

Middlesworth, L. van (1942). New practical use for plant hormone. *Fruit. Prod. J.*, 21 : 268, 280, bibl. 8.

Mitchell, J. W. (1940). Effect of naphthalene acetic acid and naphthalene acetamide on nitrogenous and carbohydrate constituents of bean plants. *Bot. Gaz.*, 101 : 688-99.

Modlibowska, I. (1945). Pollen tube growth and embryo-sac development in apples and pears. *J. Pomol.*, 21 : 57-89.

Murneek, A. E. (1933). The nature of shedding of immature apples. *Res. Bull. Mo. agric. exp. Stat.*, 201, pp. 34, bibl. 20.

———— (1940a). Reduction and delay of fruit abscission by spraying with growth substances. *Proc. Amer. Soc. hort. Sci. for 1939*, 37 : 432-4, bibl. 1. *23, 24, 120.*

———— (1940b). New practices to regulate the fruit crop. *Bull. Mo. agric. Exp. Stat.*, 416, pp. 15. *24.*

Murphy, L. M. (1941). Pre-harvest apple spraying and fruit abscission. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 123-6. *3, 71.*

———— (1942). Further studies with pre-harvest sprayed McIntosh apples. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 42-4, bibl. 3. *72.*

Overholser, E. L., Overley, F. L., Clore, W. J., and Allmendinger, D. F. (1941). Hormones, horticultural chemicals and vitamins as related to growth, fruit drop and colour. *Proc. 36th Meet. Wash. Stat. hort. Ass., 1940*, pp. 128-42, bibl. 15.

————, ————, and Allmendinger, D. F. (1942). Further studies with certain chemicals to prevent fruit drop and increase red colour. *Proc. 37th Meet. Wash. Stat. hort. Ass., 1941*, pp. 79-86, bibl. 10. *47, 48, 121.*

———, ———, ——— (1943). Three-year study of pre-harvest sprays in Washington. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 211-9, bibl. 12. *25, 26, 27, 28, 47, 48, 73, 74, 75, 122, 123, 124, 131, 132.*

———, ———, ——— (1944). Pear growing and handling in Washington. *Pop. Bull. Wash. St. agric. exp. Stat.*, 174, pp. 84, bibl. 64.

PAINTER, A. C. (1939). Farm report, marketing. *A. R. East Malling Res. Stat. for 1938*, A22, p. 22.

———, and WATES, B. L. (1939). A further experiment in thinning Victoria plums. *A. R. East Malling Res. Stat. for 1938*, A22, pp. 139-44.

PETCH, C. E. (1940). Harvest sprays with plant growth substances. *47th A. R. Quebec pomol Fruitgr. Soc.*, pp. 7-11.

PFEFFER, W. (1903). The physiology of plants, Vol. 2. Engl. Transl. by Ewart, A. J. *Clarendon Press, Oxford.*

PORTHEIM, L. (1941). Further studies on the action of heteroauxin on *Phaseous vulgaris. Ann. Bot. Lond.*, 5 : 35-46, bibl. 10.

REYNEKE, J., and PEARSE, H. L. (1945). The relationship between respiration and the physical condition of fruit as affected by oil treatments. *J. Pomol.*, 21 : 8-27.

ROBERTS, R. H. (1937). Blossom bud development and winter hardiness. *Amer. J. Bot.*, 24 : 683-5, bibl. 2.

———, and STRUCKMEYER, B. E. (1943). The efficiency of harvest sprays after a freeze. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 198. *90, 91.*

RUTH, W. A., and POWELL, D. (1944). Time of application and the effectiveness of " hormone " sprays. *Illinois St. hort. Soc. Newsletter No. 5, 29.*

SOUTHWICK, L. (1940). The McIntosh drop. *Bull. Mass. agric. Exp. Stat.*, 372, p. 19.

——— (1942). Further studies on the control of pre-harvest drop of McIntosh. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 39-41, bibl. 2. *81, 82, 83.*

——— (1943). Comparative results with sprays and dusts in controlling the pre-harvest drop of apples. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 199-202, bibl. 3. *33, 84, 85, 108, 109.*

——— (1944). Further results with sprays and dusts in controlling pre-harvest fruit drop of apples. *Proc. Amer. Soc. hort. Sci. for 1944*, 44 : 109-10, bibl. 4. *86.*

———, and SHAW, J. K. (1941a). The effect of hormone sprays on the harvest drop of apples. *Proc. Amer. Soc. hort. Sci. for 1940*, 38 : 121-2.

———, ——— (1941b). Spraying to control pre-harvest drop of apples. *Bull. Mass. agric. exp. Stat.*, 381, pp. 16, bibl. 6. *76, 77, 78, 79, 80a, 80b, 80c, 107a, 107b.*

SRIVASTAVA, D. N. (1938a). Studies in the non-setting of pears. I. Fruit drop and the effect of ringing, de-horning and branch bending. *J. Pomol.*, 16 : 39-62, bibl. 36.

——— (1938b). ——— II. The effect of weather conditions. *A. R. East Malling Res. Stat. for 1937*, A21, pp. 128-44, bibl. 16.

——— (1938b). ——— III. The effect of the flower characters. *A. R. East Malling Res. Stat. for 1937*, A21, pp. 145-53, bibl. 16.

STEER, W., and MOORE, M. H. (1941). Spray damage and apple capsid control by winter petroleum. *A. R. East Malling Res. Stat. for 1940*, A24, pp. 76-81, bibl. 12.

STRICKLAND, A. G., KEMP, H. K., and BEARE, J. A. (1941). Spraying with plant growth substances. *Fruit World, Melbourne*, 42 : 10 : 7-9, bibl. 2 and *Agric. S. Aust.* n. d. *49, 92, 142.*

STRUCKMEYER, B. E., and ROBERTS, R. H. (1942). Investigations on the time of blossom induction in Wealthy apple trees. *Proc. Amer. Soc. hort. Sci. for 1942*, 40 : 113-9, bibl. 6.

VAN STUIVENBERG, J. H. M. (1941). Het bespuiten van vruchtboomen met groeistoffen met het doel parthenocarpie te induceeren en den laten val te beinvloeden. *Mededeeling Laboratorium voor Tuinbouwplantenteelt, Wageningen, No. 35.* Overdruk uit *De Fruitteelt*, 30 (1940), 31 (1941). *12, 38, 39, 40, 43, 52, 53, 93, 102, 103, 104, 129, 133, 136, 137.*

——— (1942). De invloed van groeistoffen op de rijping en op de houdbaarheid van vruchten bij bewaring in het koelhuis. *Mededeelingen en overdrukken van het instituut voor onderzoek op het gebied van verwerking van fruit en groenten te Wageningen, 1, No. 8.*

SWARBRICK, T. (1943). The influence of certain sprays on the pre-harvest drop of apples. Progress Report *II*, *A. R. Long Ashton agric. hort. Stat. for 1942*, pp. 29-31 *1, 37.*

——— (1945). The prevention of fruit drop in apples. *A. R. Long Ashton agric. hort. Stat. for 1944*, pp. 30-36. *4, 125.*

TUKEY, H. B., and YOUNG, J. D. (1942). Gross morphology and histology of developing fruit of the apple. *Bot. Gaz.*, 104 : 1-25, bibl. 28.

TYDEMAN, H. M. (1938). The influence of different pollens on the growth and development of the fruit in apples and pears. I. A progress report on experiments carried out during 1937. *A. R. East Malling Res. Stat. for 1937*, A.21, pp.117-27, bibl. 11.

——— (1944). The influence of different pollens on the growth and development of the fruit of apples and pears. II. Fruit size and seed content in relation to fruit drop. *A. R. East Malling Res. Stat. for 1943*, A.27, pp. 31-4, bibl. 7.

VAN DOREN, A., and HOFFMAN, M. B. (1943). Thinning Wealthy apples at blossom time with a caustic spray compared with hand thinning after the June drop. *Proc. Amer. Soc. hort. Sci. for 1943*, 42 : 182.

VYVYAN, M. C. (1941). Reduction of the pre-harvest drop in apples by spraying with a growth substance. *A. R. East Malling Res. Stat. for 1940*, A.24, pp. 46-9, bibl. 1. *5, 13, 126.*

——— (1942). Further note on the reduction of pre-harvest drop in apples by use of dilute sprays of alpha-naphthaleneacetic acid. *A. R. East Malling Res. Stat. for 1941*, A.25, pp. 38-40. *87.*

——— (1943). Sprays to control pre-harvest drop of fruit. *A. R. East Malling Res. Stat. for 1942*, A.26, pp. 47-8, bibl. 2. *134.*

——— (1944). Further trials with sprays to control pre-harvest fruit drop. *A. R. East Malling Res. Stat. for 1943*, A.27, pp. 49-51.

——— (1946). Experiments with growth substance sprays for reduction of pre-harvest drop of fruit. *J. Pomol.*, 22 : 11-37. *6, 7, 8, 9, 10, 11, 14, 127, 128, 135.*

WALLACE, T., and SPINKS, G. T. (1940). A long period field experiment on the manuring of apple trees. *J. Pomol.*, 18 : 182-92, bibl. 2.

WHITTAKER, E. C., and MACKENZIE (1944). The control of pre-harvest drop of apples and pears. *The Fruitworld and Market Grower*, 45 : 2 : 5-6, and *Agric. Gaz., N.S.W.*, 55 : 11-3. *30, 50, 143.*

ZIMMERMAN, P. W., and HITCHCOCK, A. E. (1944). The aerosol method for treating plants with growth substances. *Contr. Boyce Thompson Inst.*, 13 : 7 : 313-22, bibl. 8.

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